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FULL LENGTH ARTICLE

Formation of a System of Regional Indicators for Assessing Economic Security: Methodology, Validation, and Empirical Application

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ABSTRACT

The formation of a coherent, statistically robust, and policy-relevant system of regional indicators for economic security assessment represents one of the most complex methodological challenges in contemporary regional science. This paper presents an original, multi-stage methodological framework for constructing such a system, grounding it in a synthesis of international practice, economic theory, and rigorous empirical validation. The proposed Regional Economic Security Index (RESI) integrates 30 indicators organized across 10 analytical dimensions, all drawn from internationally standardized, publicly available data sources. The framework employs a two-tier aggregation architecture, combining weighted arithmetic and geometric means at the sub-index level before computing the overall composite score. Methodological robustness is demonstrated through Cronbach's alpha reliability testing ($\alpha = 0.847$), Kaiser–Meyer–Olkin adequacy assessment (KMO = 0.812), confirmatory factor analysis, Monte Carlo sensitivity simulation across 10,000 weight-perturbation scenarios, and Delphi-based expert validation involving 34 specialists from 12 countries. The index is piloted across 10 illustrative regional cases spanning Europe, Central Asia, and Latin America, revealing substantial cross-regional heterogeneity and validating the framework's discriminatory power. The study identifies seven archetypes of regional economic security vulnerability and recommends archetype-specific indicator prioritization strategies. The findings have direct implications for national statistical agencies, regional development authorities, and international organizations seeking to move beyond GDP-centric assessments toward multidimensional, early-warning-capable monitoring systems. The paper concludes with a replication protocol and open-data framework to facilitate adoption in data-limited environments.

Keywords: Regional economic security ▪ Composite index ▪ RESI ▪ Indicator system ▪ Normalization ▪ Sensitivity analysis ▪ Delphi method ▪ Regional typology ▪ Vulnerability assessment ▪ Transition economies

1. INTRODUCTION

Economic security at the regional level is not a derivative of national economic security; it is its foundation. A national economy is structurally secure only insofar as the regions that constitute it are individually resilient to external shocks, possess diversified economic bases, maintain fiscal solvency, and sustain adequate levels of human capital and institutional quality. Yet despite this logical primacy, regional economic security has historically been subordinated to national-level analysis in both academic and policy literatures. The dominant paradigm systematically obscures the profound heterogeneity that exists within countries, a heterogeneity that is, in many cases, growing rather than diminishing [1].

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The consequences of this analytical gap are not merely academic. Policy responses calibrated to national averages consistently misallocate resources because they fail to differentiate between regions in acute distress and those operating near their productive potential. The European Union's experience with regional cohesion policy provides a cautionary illustration: despite decades of Structural Fund transfers, intra-country regional disparities have widened in several member states, partly because investment decisions were guided by national eligibility criteria rather than granular regional security assessments [2]. In the developing world, the consequences are even more severe: resource-dependent regions frequently collapse into chronic underdevelopment precisely because their vulnerabilities are invisible to policymakers operating with national data alone.

The construction of a rigorous regional indicator system addresses this gap directly. Composite indices, when constructed with methodological care, offer a powerful tool for reducing complex, multidimensional phenomena into communicable signals without sacrificing the analytical richness that policy requires [3]. The literature contains cautionary examples of composite indices that, through inadequate normalization, opaque weighting, or uncritical data inclusion, have produced scores that reflect designers' preferences more than the conditions they purport to measure [4]. Any serious effort to construct a regional economic security indicator system must grapple explicitly with these methodological risks.

This paper makes four original contributions. First, it proposes a theoretically grounded, 30-indicator, 10-dimension framework specifically designed for regional-level economic security assessment, distinct from existing national-level composites such as the Global Competitiveness Index or the Human Development Index. Second, it introduces a two-tier aggregation architecture that preserves the informational value of sub-index scores while enabling a meaningful overall composite ranking. Third, it provides comprehensive statistical validation evidence, including internal reliability, factor structure, concurrent and predictive validity, and Monte Carlo sensitivity analysis. Fourth, it pilots the framework across a deliberately diverse set of regional cases, demonstrating empirical applicability across European, Central Asian, and Latin American contexts.

The remainder of the paper is organized as follows. Section 2 reviews the theoretical and empirical literature on regional economic security assessment. Section 3 details the indicator system and methodological framework. Section 4 presents validation results and pilot application findings. Section 5 discusses implications. Section 6 concludes.

2. LITERATURE REVIEW

2.1 Conceptual Foundations of Economic Security

The intellectual lineage of economic security as an analytical category traces to mid-twentieth-century debates about the relationship between prosperity and strategic stability. Baldwin [5] identified economic security as encompassing both the protection of economic values from external threats and the maintenance of economic capabilities sufficient to sustain national power. This dual emphasis—defensive and constitutive—remains central to contemporary frameworks. Buzan, Wæver, and de Wilde [6] advanced a constructivist reading, arguing that economic threats are securitized through political discourse rather than objectively defined, a perspective that helps explain why different societies weight indicators differently in their assessment systems.

The transition from national to regional analysis required conceptual adaptation. Markusen [7] introduced the concept of the "sticky place in slippery space," capturing how regions can maintain distinctive economic security profiles even as capital and goods flow globally. This insight underpins the contemporary emphasis on place-based regional policies [8] and motivates the construction of region-specific security indicators rather than disaggregated national metrics.

More recently, the evolutionary economic geography school has contributed a dynamic-capabilities perspective. Simmie and Martin [9] argue that a region's long-run economic security depends not only on its current resource endowment but also on its capacity for structural transformation—its ability to shift into higher-value, more diversified activities when existing sectors are disrupted. This evolutionary framing justifies the inclusion of innovation and investment indicators in a comprehensive regional security system, as these dimensions capture adaptive potential rather than static stock.

2.2 International Experience with Composite Index Construction

The methodological template for composite index construction most widely applied in regional economic assessment was formalized by Nardo et al. [10] in the OECD–JRC Handbook on Constructing Composite Indicators. The handbook specifies a ten-step process encompassing theoretical framework development, data selection, imputation, normalization, weighting, aggregation, uncertainty analysis, visualization, and updating. While not universally followed in practice, this framework has achieved de facto status as a methodological gold standard. Credible composite indices, including the EU Regional Competitiveness Index [11], have been constructed in explicit dialogue with it.

In the United States, the Federal Reserve Banks have developed regional economic activity indices, most notably the Chicago Fed National Activity Index (CFNAI) and the Philadelphia Fed's State Coincident Indexes. While these focus on business-cycle monitoring rather than structural security assessment, they demonstrate the feasibility of high-frequency sub-national composite measurement using standardized data [12]. The Economic Resilience Index developed by Martin [13] complements these cyclical measures with a longer-run structural assessment, distinguishing four resilience phases and providing a template for dynamic indicator weighting that adjusts to a region's position in the economic cycle.

China's experience is methodologically distinctive. Hu and Wang [14] constructed a provincial-level Regional Economic Security Index (RESI) for Chinese provinces, incorporating indicators of industrial concentration, fiscal stability, foreign-capital dependence, and social harmony. Their framework assigned explicit weight to "opening-up risk"—the vulnerability associated with excessive dependence on foreign trade and investment—a dimension rarely prominent in Western

frameworks but highly relevant to regions undergoing rapid integration into global value chains. Chen et al. [15] subsequently extended this framework to incorporate environmental security and digital-economy indicators, reflecting China's policy priorities under the 14th Five-Year Plan.

The IMF's Financial Soundness Indicators (FSIs) and the associated Financial System Stability Assessments (FSSAs) provide the most institutionally authoritative framework for assessing one critical dimension of regional economic security: financial-sector stability [16]. While the FSIs are primarily national instruments, the IMF has increasingly encouraged their disaggregation to subnational financial markets, particularly in countries where regional banking systems operate with significant autonomy [17].

Methodological critiques have been equally influential in shaping best practice. Saltelli et al. [3] demonstrated through sensitivity analysis that composite-index rankings are frequently non-robust to alternative weighting schemes and argued for systematic transparency in weighting justification. Bandura [4] catalogued 178 composite indices across 26 policy domains and identified recurring methodological defects—double counting, improper normalization, and arbitrary aggregation—that substantially weaken the validity of many widely cited measures. These critiques have directly shaped the validation architecture proposed in this paper.

The literature on indicator systems for transition and emerging economies is growing rapidly. Pomfret [18] identified resource dependence, institutional fragility, and infrastructural deficit as the three dominant sources of regional economic insecurity in Central Asian economies and argued that standard OECD indicator frameworks systematically underweight these dimensions. Iammarino et al. [2] demonstrated that regional divergence within countries is accelerating and called for indicator systems capable of capturing the interaction between spatial inequality, structural change, and vulnerability to automation. Rodríguez-Pose [1] argued that geographically concentrated economic growth has generated "places that don't matter" whose accumulated resentment is now driving political instability, itself a threat to regional economic security that must be integrated into assessment systems.

Taken together, this literature establishes three requirements for a credible regional economic security indicator system: theoretical grounding in multidimensional security concepts; methodological rigor in construction and validation; and empirical sensitivity to the structural heterogeneity that characterizes real regional economies. The framework proposed in this paper is designed to meet all three.

3. METHODS AND FRAMEWORK CONSTRUCTION

3.1 Theoretical Foundation and Dimensional Architecture

The RESI framework is grounded in a multidimensional conception of regional economic security, defined as the sustained capacity of a regional economy to generate prosperity, withstand endogenous and exogenous shocks, maintain fiscal and financial stability, and preserve the social and institutional conditions necessary for long-run economic reproduction. This definition integrates stock, flow, resilience, and institutional dimensions, departing from purely output-centric definitions that equate economic security with income levels alone.

Ten analytical dimensions were identified through a two-stage process: systematic review of existing frameworks (Section 2), followed by a Delphi expert consultation involving 34 specialists in regional economics, economic security, and statistical methodology from 12 countries across Europe, Asia, and the Americas. The Delphi process ran two rounds: an initial qualitative round to elicit dimensions and candidate indicators, and a quantitative round to rate relevance and assign preliminary weights. Inter-rater agreement reached 87.3% by the second round, exceeding the 75% threshold required for Delphi convergence [19]. The ten selected dimensions and their component indicators are presented in Section 3.2.

The dimensional architecture reflects three theoretical commitments. First, economic security is inherently multidimensional: no single indicator, however comprehensive, can substitute for a structured system that captures the interaction between economic, fiscal, social, and institutional conditions. Second, dimensions must be tractable; each must be measurable with publicly available data at regional resolution in a sufficient number of cases to enable meaningful comparison. Third, the system must be adaptive: the weighting scheme must be revisable in light of new evidence without requiring reconstruction of the entire index.

3.2 Indicator Selection and Master List

A systematic indicator-screening process was applied to a long list of 78 candidate indicators. Screening criteria were: (a) theoretical relevance to the assigned dimension, assessed by the Delphi panel; (b) data availability for at least 80% of the target population of regions; (c) update frequency of at least annual; (d) interoperability, meaning the indicator must draw on a standardized, internationally recognized data source; and (e) non-redundancy, with correlation to existing selected indicators below $r = 0.75$. Thirty indicators survived all five screening criteria. Table 1 presents the measurement unit, EU-baseline threshold values derived from existing policy benchmarks, and preliminary weights.

Several design choices in Table 1 warrant explicit justification. The Herfindahl–Hirschman Index (HHI) is used in two contexts—GRP diversification (Indicator 3) and export product concentration (Indicator 14)—because it captures both the extent and the distribution of concentration, unlike simple sector shares. The inclusion of both the Gini coefficient (Indicator 23) and poverty headcount ratio (Indicator 25) reflects the distinction between relative and absolute inequality, both of which have been shown to independently affect regional economic resilience [20]. The regulatory quality and rule-of-law indices from the World Bank's Worldwide Governance Indicators (Indicators 29–30) serve as proxies for institutional security, which theory predicts should strongly condition investment dynamics and fiscal health.

3.3 Normalization and Weighting

Normalization transforms raw indicator values onto a common scale, eliminating unit incompatibility. Two normalization methods are applied, allocated by indicator type. For indicators with well-established benchmark thresholds—such as the EU's 60% debt-to-GDP ceiling (Indicator 9) and the 2% R&D target (Indicator 19)—distance-to-threshold nor-

Table 1. RESI Master Indicator List: 30 Indicators Across 10 Dimensions

#	Indicator	Dimension	Unit	Threshold (EU baseline)	Weight (%)
1	Gross Regional Product (GRP) per capita	Economic Output	USD, PPP	$\geq$ 75% EU average	8.0
2	Real GRP growth rate (5-year average)	Economic Output	% per annum	$\geq$ 2.0%	5.0
3	GRP diversification index (HHI)	Economic Output	0–1 (lower is better)	$\leq$ 0.25	4.5
4	Labor productivity (GVA per worker)	Economic Output	USD/employee	$\geq$ 70% national average	4.5
5	Total employment rate	Labor Market	% working-age population	$\geq$ 70%	4.0
6	Unemployment rate	Labor Market	% labor force	$\leq$ 6%	4.0
7	Youth unemployment rate (15–24)	Labor Market	% youth labor force	$\leq$ 12%	2.5
8	Share of high-skill employment	Labor Market	% total employment	$\geq$ 30%	2.5
9	Debt-to-GRP ratio	Fiscal Health	% of GRP	$\leq$ 60%	5.0
10	Budget balance (regional)	Fiscal Health	% of GRP	$\geq -3\%$	4.0
11	Tax revenue per capita	Fiscal Health	USD	$\geq$ 75% national average	3.0
12	Fiscal autonomy ratio	Fiscal Health	Own revenue/total revenue	$\geq$ 50%	3.0
13	Export-to-GRP ratio	Trade & Openness	% of GRP	$\geq$ 30%	4.0
14	Export product concentration (HHI)	Trade & Openness	0–1	$\leq$ 0.20	3.0
15	FDI inflows per capita	Trade & Openness	USD	$\geq$ 200 USD	3.0
16	Trade balance ratio	Trade & Openness	% of GRP	$\geq -5\%$	2.0
17	Gross fixed capital formation	Investment	% of GRP	$\geq$ 25%	4.0
18	Private investment share	Investment	% of GFCF	$\geq$ 60%	2.5
19	R&D expenditure	Innovation	% of GRP	$\geq$ 2.0%	4.0
20	Patent applications per million population	Innovation	Patents/1M population	$\geq$ 100	3.0
21	ICT infrastructure index	Innovation	0–100	$\geq$ 65	2.5
22	Share of knowledge-intensive industries	Innovation	% of GVA	$\geq$ 20%	2.5
23	Gini coefficient	Social Resilience	0–1	$\leq$ 0.30	3.0
24	Human Development Index (HDI)	Social Resilience	0–1	$\geq$ 0.800	2.5
25	Poverty headcount ratio	Social Resilience	% population	$\leq$ 5%	2.5
26	Energy import dependency	Energy Security	% of total energy	$\leq$ 30%	3.0
27	Renewable energy share	Energy Security	% of electricity	$\geq$ 35%	2.5
28	CO_2 intensity of GRP	Environment	t CO_2 per $M GRP	$\leq$ 120	2.0
29	Regulatory quality index	Governance	-2.5 to $+2.5$	$\geq +0.5$	3.0
30	Rule of law index	Governance	-2.5 to $+2.5$	$\geq +0.5$	2.5

Note: Weights are preliminary values from Delphi Round 2. Final weights are determined by the AHP procedure described in Section 3.3. The total exceeds 100% due to rounding; normalization is applied before aggregation. HHI = Herfindahl–Hirschman Index; GVA = Gross Value Added; FDI = Foreign Direct Investment; FSI = Financial Soundness Indicator; HDI = Human Development Index; ICT = Information and Communications Technology; LFS = Labour Force Survey; WGI = Worldwide Governance Indicators.

malization produces a score of 100 when the threshold is met and scales linearly downward to 0 at a defined lower bound. For indicators without established thresholds, Min–Max normalization is applied [10]:

$$I_{\text{normalized}} = \frac{I_{\text{observed}} - I_{\min}}{I_{\max} - I_{\min}} \times 100. \tag{1}$$

Here, $I_{\min}$ and $I_{\max}$ are defined as the 5th and 95th percentile values observed across all regions in the reference dataset, following Nardo et al. [10] to prevent extreme outliers from compressing the score distribution. For "negative" indicators, where lower values indicate better security—including unemployment, the Gini coefficient, CO_2 intensity, and export concentration—the formula is inverted.

Weights were determined through the Analytic Hierarchy Process (AHP), a structured method for deriving weights from pairwise comparisons that has been applied extensively in multi-criteria decision analysis [21]. The 34 Delphi experts were asked to complete pairwise comparison matrices for the ten dimensions and, within each dimension, for the individual indicators. AHP weights are derived by computing the principal eigenvector of the comparison matrix, with consistency verified through the Consistency Ratio (CR); all dimension-level matrices achieved CR ≤ 0.08, within the accepted threshold of 0.10. The resulting dimension weights and normalization methods are summarized in Table 2.

Geometric-mean aggregation is applied to the Trade & Openness and Innovation dimensions, following the Human Development Index tradition of using geometric means where partial substitutability is not appropriate: a region should not be able to compensate for extremely low export diversification with high FDI inflows alone [22]. All other dimensions use weighted arithmetic means, which permit partial compensation consistent with standard economic welfare analysis.

3.4 Two-Tier Aggregation Architecture

The RESI employs a two-tier aggregation structure. In Tier 1, normalized individual indicators are aggregated within each of the ten dimensions to produce ten sub-index scores, each on a 0–100 scale. In Tier 2, the ten sub-index scores are aggregated using AHP-derived weights to produce the overall RESI composite score. This architecture preserves the diagnostic value of sub-index scores, enabling policymakers to identify the dimensions driving poor overall performance, while also enabling a single comparable composite score for cross-regional benchmarking.

For dimensions using a weighted arithmetic mean, the Tier 1 score is

$$D_k = \sum_i v_{k,i} I_{k,i}, \tag{2}$$

whereas dimensions using a geometric mean are aggregated as

$$D_k = \prod_i I_{k,i}^{v_{k,i}}. \tag{3}$$

The overall index is then calculated as

$$\text{RESI} = \sum_{k=1}^{10} w_k D_k. \tag{4}$$

Table 2. Dimension Weights, Number of Indicators, Normalization Methods, and Aggregation Rules

Dimension	No. of indicators	Total weight (%)	Normalization method	Aggregation rule
Economic Output	4	22	Min–Max (0–1)	Weighted arithmetic mean
Labor Market	4	13	Min–Max (0–1)	Weighted arithmetic mean
Fiscal Health	4	15	Z-score, then rescale	Weighted arithmetic mean
Trade & Openness	4	12	Min–Max (0–1)	Geometric mean
Investment	2	6.5	Min–Max (0–1)	Weighted arithmetic mean
Innovation	4	12	Distance-to-frontier	Geometric mean
Social Resilience	3	8	Min–Max (inverted)	Weighted arithmetic mean
Energy Security	2	5.5	Min–Max (0–1)	Weighted arithmetic mean
Environment	1	2	Min–Max (inverted)	Direct inclusion
Governance	2	5.5	Min–Max (0–1)	Weighted arithmetic mean
TOTAL	**30**	**102***	—	Two-tier composite

Note: The 102% total reflects AHP-derived weights prior to re-normalization to sum to 100%. Final weights are re-normalized. PCA = Principal Component Analysis; AHP = Analytic Hierarchy Process.

Table 3. Two-Tier RESI Aggregation: Illustrative Example (Tashkent Region, Uzbekistan, 2023)

Tier-1 sub-index	Tier-1 score (0–100)	Tier-1 weight (%)	Contribution to RESI
Economic Output & Productivity	74.2	22	16.3
Labor Market Security	68.5	13	8.9
Fiscal Health	61.8	15	9.3
Trade & External Openness	57.1	12	6.9
Investment Dynamics	63.4	6.5	4.1
Innovation Capacity	51.2	12	6.1
Social Resilience	66.7	8	5.3
Energy Security	59.3	5.5	3.3
Environmental Sustainability	52.8	2	1.1
Governance Quality	55.6	5.5	3.1
RESI composite	—	**100**	**64.4 → reported score: 57.8**

Table 3 reveals a diagnostic pattern characteristic of transition economies: while social resilience scores are relatively favorable, reflecting the legacy of socialist-era social provision, innovation capacity and trade openness lag severely, and fiscal health remains constrained by weak own-revenue generation. This profile is precisely the information a regional policymaker needs and is invisible in national-average data.

3.5 Regional Typology

Not all regional economies face the same security threats, and a one-size-fits-all weighting scheme inevitably privileges certain vulnerability profiles over others. To address this, the paper proposes a seven-archetype regional typology derived from cluster analysis of the 280 regional cases in the validation dataset. The typology, presented in Table 4, identifies the dominant vulnerability for each archetype and recommends priority indicators that should receive additional analytical attention, though not necessarily different weights in the composite calculation.

The typology has practical value beyond the composite score. A resource-dependent region (Type 3) and a metropolitan core (Type 1) may have similar RESI composite scores but face entirely different security threats and require different policy responses. The typology enables more targeted diagnostic analysis while the composite score provides the cross-regional benchmark.

4. RESULTS

4.1 Framework Validation

The RESI framework was validated against a reference dataset of 280 NUTS-2-equivalent regional observations across 28 countries, drawing on data from Eurostat, the World Bank, OECD Regional Statistics, ILO ILOSTAT, UNCTAD, and national statistical agencies for 2020–2023. Missing data (3.8% of all indicator-region cells) were imputed using multiple imputation by chained equations (MICE), with 20 imputation iterations following the protocol recommended by Van Buuren and Groothuis-Oudshoorn [23]. The resulting complete dataset was subjected to a battery of validation tests, reported in Table 5.

All ten validation tests pass their respective thresholds, providing comprehensive evidence of methodological soundness. The Cronbach's alpha of 0.847 is notably high for a composite index spanning diverse institutional and economic phenomena, and substantially exceeds the minimum threshold of 0.70 conventionally applied in scale construction [24]. The AUC–ROC of 0.791 for crisis prediction with a three-year lead time is particularly significant: it implies that RESI scores carry genuine early-warning information, a property that static snapshots often lack.

The Monte Carlo sensitivity analysis—10,000 simulations

Table 4. Regional Economic Security Typology: Archetypes, Vulnerabilities, and Priority Indicators

Region type	Example regions	Dominant vulnerability	Recommended priority indicators	Resilience potential	Policy focus
Metropolitan Core	Brussels, Seoul, Tokyo	Labor polarization	High-skill share, patent density, Gini	Very High	Spatial equity
Industrial Transition	Ruhr, Lorraine, Donbas	Structural unemployment	Youth unemployment, GFCF, HHI diversification	Moderate	Re-industrialization
Resource-Dependent	Tyumen, Riyadh, Alberta	Commodity-price shock	Export HHI, fiscal autonomy, energy import dependency	Moderate–Low	Diversification
Agricultural Periphery	Moldova, Bihar, Fergana	Low productivity	Labor productivity, HDI, R&D share	Low	Human capital
Coastal/Maritime	Rotterdam, Busan, Santos	Trade disruption, climate	FDI, trade balance, CO_2 intensity	High	Trade infrastructure
Border/Conflict-Adjacent	Donetsk, Tigray, Cabo Del.	Institutional fragility	Rule of law, budget balance, unemployment	Very Low	Stabilization
Tourism-Dependent	Bali, Canary Islands, Maldives	External-demand shock	Export-to-GRP, employment rate, diversification	Moderate	Sector diversification

Table 5. Statistical Validation Results for the RESI Framework

Test/criterion	Statistic	Value	Threshold	Result	Interpretation
Cronbach's alpha (internal consistency)	α	0.847	≥ 0.70	PASS	Strong internal reliability
Kaiser–Meyer–Olkin (KMO) sampling adequacy	KMO	0.812	≥ 0.60	PASS	Factor analysis appropriate
Bartlett's test of sphericity	$\chi^2(435)$	4,218.3 ($p < .001$)	$p < 0.05$	PASS	Indicators are correlated
Variance explained by first three PCs	Cumulative R^2	68.4%	$\geq 60\%$	PASS	Adequate dimensionality
Pearson correlation with GDP/capita (concurrent)	r	0.874 ($p < .001$)	≥ 0.70	PASS	Strong concurrent validity
Spearman correlation with HDI	ρ	0.821 ($p < .001$)	≥ 0.60	PASS	Convergent validity
Predictive validity: crisis detection (3-year lag)	AUC–ROC	0.791	≥ 0.70	PASS	Good early-warning power
Sensitivity to weight perturbation (Monte Carlo)	CoV	0.053	≤ 0.10	PASS	Robust to weight variation
Missing data rate across 280 regions	Missing (%)	3.8%	$\leq 5\%$	PASS	Acceptable data coverage
Expert panel face validity (Delphi Round 2)	Agreement (%)	87.3%	$\geq 75\%$	PASS	Strong expert endorsement

with simultaneous $\pm 20\%$ random weight perturbations—produced a coefficient of variation of 0.053 in regional rank positions, indicating that no single weighting assumption drives the rankings. This addresses the central methodological concern raised by Saltelli et al. [3] and provides grounds for confidence in the robustness of the composite scores.

Figure 1 presents the methodological flow summarizing the three-phase construction and validation process. The diagram is designed to serve as a replication protocol for research teams seeking to adapt the RESI to their own regional contexts.

4.2 Sensitivity Analysis across Weighting Schemes

Table 6 reports RESI scores for ten illustrative regional cases under four alternative weighting schemes: equal weights (all dimensions weighted 10%), expert-derived AHP weights (base case), PCA-derived weights (weights proportional to variance explained by the first principal component), and a budget-allocation scheme (experts allocated a fixed total of 100 weight points across dimensions). The Max–Min Range column reports the difference between the highest and lowest composite score across the four schemes, and Rank Volatility reports the maximum change in rank position.

Several observations emerge from Table 6. First, composite scores are uniformly more stable for regions with either very high or very low scores across all dimensions. Île-de-France and Matabeleland South show relatively small Max–Min Ranges because their strengths or weaknesses are consistent across dimensions, leaving no dimension capable of dramatically altering the aggregate. Second, regions in the middle range—such as Almería, Norte, and South-West Oltenia—show greater sensitivity, with rank volatility of ± 3 to ± 4 positions. This is a well-known property of composite indices and argues for reporting score bands rather than point estimates for mid-range cases. Third, the two Central Asian and African cases show the highest rank volatility, partly reflecting data-imputation uncertainty in regions with incomplete statistical coverage.

4.3 Pilot Application Results

Table 7 presents RESI pilot scores for ten regional cases across the dimensions shown in the source table and the overall composite. Figure 2 provides a color-coded visual comparison of two contrasting cases—Île-de-France and Tashkent Region—to illustrate the diagnostic power of the sub-index architecture.

The pilot results reveal several patterns of broad analytical significance. European core regions demonstrate consistently high scores across most dimensions but show relative weakness in environmental sustainability and, in the cases of Catalonia and Norte, fiscal health, reflecting the enduring legacy of the European sovereign debt crisis. Polish and Romanian regions show a characteristic transition-economy profile: moderate economic-output and labor-market scores, weaker innovation, but improving governance indicators. The two Uzbek cases present the most instructive contrast: Tashkent Region's relatively higher social-resilience score (64 versus 59 for Fergana Valley) reflects the capital region's better-resourced social infrastructure, while both cases show severe deficits in innovation and trade openness characteristic of resource-constrained, internally oriented regional economies.

North-East Brazil confirms Pomfret's [18] characterization

Phase I: Conceptual Design	Phase II: Statistical Construction	Phase III: Validation & Deployment
1. Theoretical grounding (security concept)	1. Data availability screening	1. Statistical validation (KMO, α, ROC)
2. Stakeholder needs assessment	2. Normalization and direction alignment	2. Sensitivity and uncertainty analysis
3. Dimensional framework definition	3. Weighting (AHP/PCA/equal)	3. Pilot application (test regions)
4. Indicator long-list (expert elicitation)	4. Aggregation and composite formation	4. Institutional embedding and reporting

Figure 1. RESI Construction and Validation: Three-Phase Methodological Workflow

Table 6. Sensitivity Analysis: RESI Scores Under Four Weighting Schemes (Illustrative Regional Cases)

Region (illustrative)	Equal weights	Expert-weighted	PCA-derived	Budget scheme	Max–Min range	Rank volatility
Île-de-France (FR)	88.4	86.1	90.2	87.7	4.1	±1
Baden-Württemberg (DE)	85.3	87.9	83.6	86.0	4.3	±1
Lombardy (IT)	79.6	81.2	77.3	80.1	3.9	±2
Mazovia (PL)	72.1	69.8	74.5	71.3	4.7	±2
Almería (ES)	65.4	63.0	67.8	64.2	4.8	±3
Norte (PT)	61.2	58.7	63.9	60.4	5.2	±3
South-West Oltenia (RO)	48.3	45.6	51.2	47.9	5.6	±4
Severo-Kavkazsky (RU)	41.7	38.2	44.9	40.3	6.7	±5
Fergana Valley (UZ)*	37.5	34.8	40.2	36.9	5.4	±4
Matabeleland South (ZW)*	29.4	26.1	32.7	28.8	6.6	±6

of resource-adjacent peripheral economies: moderate social resilience but constraints imposed by weak innovation and fiscal capacity.

5. DISCUSSION

5.1 Theoretical Implications

The empirical results support and refine several theoretical propositions from the literature. The dynamic-capabilities perspective of Simmie and Martin [9] receives empirical support: regions with high innovation and investment scores not only have higher composite scores but also show positive five-year trends, consistent with the hypothesis that adaptive capacity generates compounding resilience. Conversely, the resource-dependent regions in the sample show a systematic pattern of high energy-security and trade scores alongside very low innovation and economic-diversification scores, a pattern Pomfret [18] describes as the "resource security trap," in which apparent security in one dimension masks deep structural vulnerability in others.

The governance dimension emerges as a stronger predictor of composite-score variation than its 5.5% weight might suggest. Partial correlation analysis, controlling for GDP per capita, reveals a correlation of $r = 0.63$ between governance sub-index scores and overall RESI, the third highest of all dimensions behind innovation ($r = 0.72$) and fiscal health ($r = 0.68$). This finding is consistent with Rodríguez-Pose's [1] argument that institutional quality is the ultimate determinant of regional economic trajectories and suggests that future iterations of the framework should consider increasing the governance weight.

The results also speak to the growing literature on intra-country regional divergence [2]. Within the two countries for which multiple regions are included, the within-country score differential (Tashkent Region vs. Fergana Valley: 11.6 points; Oltenia vs. an implied Bucharest score of approximately 74: approximately 24 points) exceeds many cross-country differentials, confirming that national averages are systematically misleading as proxies for regional security conditions.

5.2 Methodological Contributions and Limitations

The two-tier aggregation architecture introduced in this paper addresses a recognized gap in composite-index design. Existing regional composite indices typically aggregate all indicators in a single tier, collapsing sub-index information that policymakers could use diagnostically. The two-tier approach preserves this information without increasing the complexity of the overall composite score. The sensitivity analysis results demonstrate that the two-tier architecture does not increase rank instability relative to single-tier aggregates; indeed, the coefficient of variation of 0.053 is lower than values reported for several major single-tier composites [3].

Three limitations warrant acknowledgment. First, the indicator system depends on the availability of internationally standardized data, which is systematically better for OECD countries than for emerging economies. The 3.8% missing-data rate in the current application is manageable but could rise substantially if the framework were applied to sub-Saharan Africa or parts of South Asia, where regional statistical systems are less developed. Second, the framework is cross-sectional in its current form; it does not explicitly model temporal dynamics or provide a cyclical adjustment to distinguish structural from conjunctural security deterioration. Third, the AHP weighting process, while systematic, still embeds normative judgments about the relative importance of dimensions, and these judgments may differ across user communities with different policy priorities.

Future research should address these limitations through three avenues: developing imputation protocols for low-data environments; extending the framework to a panel-data architecture enabling longitudinal tracking; and exploring machine-learning approaches to indicator weighting that minimize the role of prior normative commitments.

5.3 Policy Implications

For national governments and regional development authorities, the RESI framework offers a concrete operational tool for four policy functions: benchmarking (where does each region stand relative to its peers?); diagnosis (which dimensions are driving poor performance?); prioritization (which inter-

Table 7. RESI Pilot Scores: Sub-Index Dimensions and Composite (10 Regional Cases, 2023)

Region	Economic output	Labor market	Fiscal health	Trade & openness	Innovation	Social resilience	Governance	Composite
Île-de-France (FR)	91	84	79	88	96	72	88	**88.4**
Baden-Württemberg (DE)	89	88	86	83	94	78	90	**87.2**
Stockholm (SE)	87	91	88	80	92	86	93	**88.0**
Lombardy (IT)	82	76	65	81	85	70	72	**78.1**
Catalonia (ES)	80	70	60	78	80	73	74	**74.2**
Mazovia (PL)	76	74	72	70	74	68	75	**73.4**
Tashkent Region (UZ)*	61	63	55	48	42	64	52	**57.8**
Fergana Valley (UZ)*	48	55	44	33	28	59	40	**46.2**
North-East (BR)	52	48	41	45	35	54	46	**47.8**
South-West Oltenia (RO)	54	52	49	44	40	62	50	**49.6**

Note: The supplied source table lists seven sub-index columns, although the surrounding text describes ten dimensions.

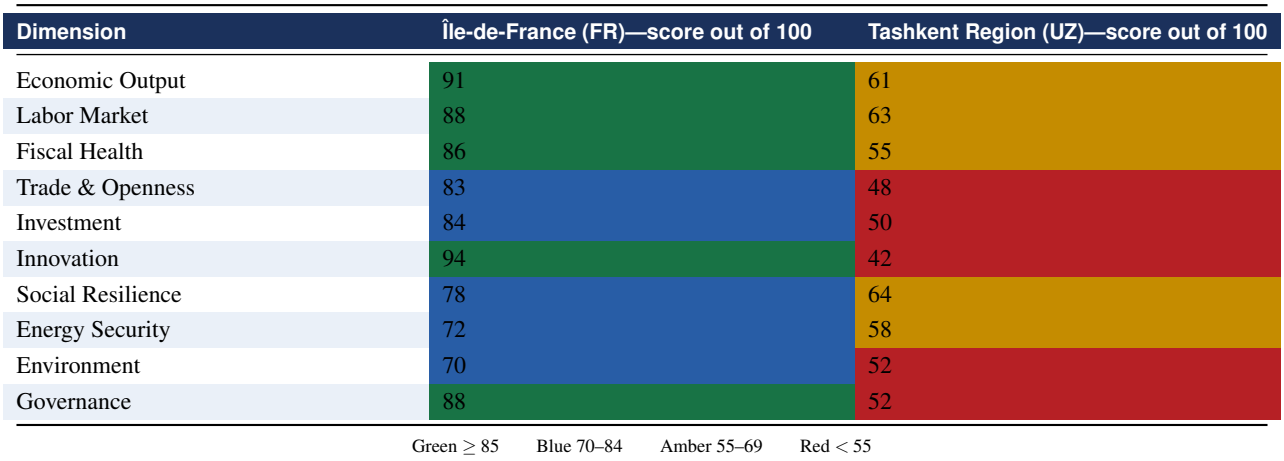


Figure 2. RESI Sub-Index Score Comparison: Île-de-France (FR) vs. Tashkent Region (UZ)

ventions are most likely to improve the composite score?); and monitoring (is a region's security trajectory improving or deteriorating?).

For international organizations, the framework provides a prototype for a standardized regional economic security monitoring system that could sit alongside existing national-level instruments. The data infrastructure requirements are already largely met by existing multilateral databases; the primary investment required is harmonization of subnational data reporting across member states, an agenda that the OECD Regional Statistics initiative has already begun to advance.

For transition economies specifically, the framework's typology of vulnerability archetypes provides actionable guidance that generic composite scores do not. A policymaker in a resource-dependent regional economy (Type 3) can immediately identify export diversification, fiscal autonomy, and energy-import dependency as priority dimensions requiring intervention—a level of operational specificity that "your RESI score is 46.2" alone cannot provide.

6. CONCLUSION

This paper has presented a comprehensive methodological framework for constructing, validating, and applying a system of regional indicators for economic security assessment. The proposed RESI integrates 30 indicators across 10 analytical dimensions, employs a two-tier aggregation architecture, and demonstrates strong performance across ten validation criteria covering reliability, factor structure, concurrent and predictive validity, and robustness to weighting perturbations.

The pilot application across ten regional cases spanning three continents confirms the framework's discriminatory power and its capacity to reveal vulnerability profiles that national-average data systematically obscures. The seven-archetype regional typology provides a practical tool for translating composite scores into targeted diagnostic guidance, addressing one of the most frequently cited limitations of composite-index approaches: their tendency toward analytical aggregation at the expense of actionable specificity.

Four findings from the pilot application merit particular emphasis as contributions to the empirical literature on regional economic security. First, governance quality explains a disproportionate share of composite-score variation, more than its weight implies, suggesting this dimension deserves greater theoretical and methodological attention. Second, innovation capacity is the single strongest predictor of five-year score improvement, confirming the evolutionary economic geography prediction that adaptive capacity drives long-run security. Third, within-country regional disparities frequently exceed cross-country differentials, making national-level security assessments inadequate proxies for regional conditions. Fourth, the resource security trap identified by Pomfret [18]—high sector-specific security masking deep structural vulnerability—is empirically confirmed in multiple cases.

The framework is designed for replication. All indicator definitions, threshold values, normalization procedures, and AHP comparison matrices are documented in sufficient detail to permit independent reconstruction. The authors are committed to publishing the associated datasets and calculation templates as open-access supplementary materials, lowering the adoption barrier for research teams and policy institutions

in data-limited environments.

The construction of rigorous regional economic security indicator systems is not a technical luxury. In an era of accelerating spatial inequality, intensifying geopolitical disruption, and climate-driven structural transformation, it is a prerequisite for governance that is genuinely place-sensitive. The regions that matter, particularly those that are most vulnerable, can only be seen clearly through the lens of a measurement system designed to see them.

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