

Italy's National Recovery and Resilience Plan and Municipal Performance through the lens of composite indicators*

F. Mariani F. Fiorillo E. Merkaj M.C. Recchioni L. Salvati
R. Santolini B. Ermini

Department of Economics and Social Sciences
Università Politecnica delle Marche

PRIN PNRR 2022 Workshop Valutazione d'impatto del PNRR sui Comuni Italiani
Ancona, February 3th, 2026

*Research project "A survey-based Impact Evaluation of PNRR on Italian Municipalities" - PRIN 2022 PNRR (Project code P2022RR82F, CUP I53D23007340001) financed by the European Union - NextGenerationEU within the National Recovery and Resilience Plan - Mission 4 "Education and Research" - Component 2 "From research to enterprise" - Investment 1.1 "National Research Programme and Projects of National Interest (PRIN).

Analysis Objectives: The PNRR Transformation Potential

This study evaluates the transformative impact of the PNRR based on the expectations of funded Municipalities:

- **Comparative Analysis:** Systematic comparison of the **Baseline** (Without PNRR) scenario vs. the **Expected Impact** (With PNRR) scenario.
- **Latent Dimensions:** Identifying the actual pillars driving projected change beyond individual raw indicators.
- **Sectoral Synergies:** Verifying if planned funds create new links between areas (e.g., if Digitalization is expected to boost Social Impact).
- **Indicator Synthesis:** Constructing **Composite Indicators** to move from raw expectations to single performance scores.

Ultimate Goal

To provide an objective measure of the transformation capacity of Municipalities as projected by PNRR investment goals.

The Dataset

- **Sample:** 376 Italian Municipalities that provided complete responses for both scenarios.
- **Indicators:** 11 key variables collected for **Baseline** and **Expected** scenarios.

Synthesis Pathway:

- 1 **Dimensional Analysis:** EFA + CFA identified 4 latent domains (Sustainability, Attractiveness, Wellbeing, Digitalization).
- 2 **Normalization:** Rescaling data for scenario comparability.
- 3 **Domain Aggregation:**
 - **Mean:** Absolute performance level.
 - **MPI (Mazziotta-Pareto):** Penalty for goal imbalance; rewards horizontal growth.

Indicator Legend (PNRR Dataset)

1. Energy efficiency
2. Consumption savings
3. Renewable capacity

4. Tourism development
5. New residents attraction
6. Building accessibility
7. Social inclusion
8. Socio-economic wellbeing

9. Citizen-oriented services
10. Business-oriented services
11. Authority digitalization

The Raw Data Problem

Analyzing 11 separate graphs would not reveal the "general" **expected impact** of the PNRR. Responses are often correlated (redundant).

Information Synthesis: The Role of Factor Analysis

- **Objective:** Reduce the complexity of 11 observed variables into 4 **Latent Dimensions** (the "drivers" of change).

The Underlying Logic

If a Municipality projects consistent impacts across a group of indicators, FA isolates the "**Common Signal**" and filters out the noise/redundancy.

- 1 **Latent Measurement:** Captures dimensions that are not directly observable.
- 2 **Redundancy Removal:** Eliminates the "double-counting" of correlated responses.
- 3 **Error Mitigation:** Distinguishes genuine expectations from respondent bias.

This process ensures that the composite indicators are built on statistically homogeneous and independent pillars.

The Transformation

11 Observed Variables

↓ *FA Processing* ↓

4 Latent Factors
(Targeted Policy Areas)

Decomposing Municipal Expectations: Signal vs. Noise

- Every reported expectation X is a composite of a shared trend and local specificities:

$$X = \underbrace{\lambda_1 F_1 + \lambda_2 F_2 + \dots}_{\text{Signal (Common Factors)}} + \underbrace{\epsilon}_{\text{Noise (Unique Component)}}$$

1. The Signal (Commonality)

The part of the response driven by the **actual PNRR projected impact**.

- **Factors (F):** The latent dimensions (e.g., Digitalization).
- **Loadings (λ):** The strength of the link between the question and the domain.

2. The Noise (Uniqueness)

The part unrelated to the general PNRR trend.

- Includes **reporting errors**, respondent bias, or extreme local technicalities.
- *Goal:* Factor Analysis filters this out to isolate the "genuine" signal.

Methodological Insight

By focusing on the Signal, we ensure that our composite indicators reflect the structural impact of the PNRR rather than idiosyncratic survey noise.

- **Estimation: Full Information Maximum Likelihood (FIML)** was used to preserve sample power and maximize the information extracted from the survey.

1. Analysis Engine

- **Exploratory (EFA):** Identifies the natural structure of expectations using *Oblimin* rotation (allowing correlation).
- **Confirmatory (CFA):** Validates the fit of the domain structure (RMSEA, CFI).

2. From 3 to 4 Factors

Empirical evidence shifted the model toward a more granular structure:

- **Initial:** Sustainability, Wellbeing, Digitalization.
- **Optimal:** Splitting Wellbeing items to isolate **Attractiveness & Accessibility**.

Key Finding

EFA and CFA evidence confirm that Municipalities perceive **Sustainability** and **Social Attractiveness** as distinct investment tracks, requiring separate composite indicators.

Statistical Validation: 3 vs. 4 Factors

The 4-factor model is statistically superior for both Baseline and Expected scenarios:

Fit Index	Baseline		Expected	
	3 Fact.	4 Fact.	3 Fact.	4 Fact.
Explained Variance	73.2%	82.5%	60.7%	69.0%
RMSEA (Error)	0.204	0.000	0.161	0.000
CFI (Quality)	0.908	1.000	0.927	1.000

What do these indices measure?

- **RMSEA (The "Residual" Error):** It measures the gap between our theoretical model and the actual responses.
- **CFI (The "Closeness" to Ideal):** It compares our model to a "worst-case" scenario (where variables have no connection).
- **Explained Variance:** It represents how much "useful information" we have captured.

Domain Composition: The 4 Pillars of PNRR Impact

F1: Sustainability

- Energy efficiency
- **Consumption savings**
- Renewable capacity

F3: Socio-Economic Wellbeing

- **Social inclusion**
- Socio-economic wellbeing

F2: Attractiveness and Accesibility

- Tourism development
- New residents attraction
- **Building accessibility**

F4: Digitalization

- Citizen-oriented services
- Business-oriented services
- **Authority digitalization**

Methodological Note

The 11 original variables have been aggregated based on their highest factor loadings, ensuring that each pillar represents a statistically independent dimension of the expected PNRR impact.

Pillars Evolution: Baseline vs. Expected Scenario

Comparison of leading indicators (loadings) and structural shifts across the 4 domains.

Pillar	Baseline (Current State)	Expected (PNRR Impact)
Sustainability	Consumption saving is the primary driver.	Energy efficiency remains the anchor of the pillar.
Attractiveness	Tourism only. New resident attraction is "Noise".	Integrated: Building accessibility and New resident attraction become a single signal.
Wellbeing	Highly redundant with Attractiveness (Corr. ~ 0.96).	Distinct Pillar: Centered on Social Inclusion.
Digitalization	Fragmented services.	Synergistic: High impact on Authority digitalization.

Key Variable Shift: Pillar Attractiveness and Accesibility

In the Baseline, **Attracting Residents** is an outlier. The PNRR "activates" it, linking demographic growth to territorial attractiveness.

Focus on Wellbeing

The expected scenario separates **Social Inclusion** from general attractiveness, creating a more specialized and autonomous policy area.

Methodology: Index Construction and Aggregation

- Two approaches are compared to evaluate the projected impact for Municipality i in domain d :

1. Arithmetic Mean (M_{id})

$$M_{id} = \frac{\sum_{j=1}^n z_{ij}}{n}$$

- **Average Intensity:** Measures the expected impact level.
- **Compensatory:** High results offset lower ones.

2. Mazziotta-Pareto (MPI)

$$MPI_{id} = M_{id} - (S_{id} \cdot cv_{id})$$

- **Consistency:** Penalizes unbalanced results (horizontal variability).
- **Non-compensatory:** Rewards homogeneity.

Note: The penalty term is composed of:

- $S_{id} = \sqrt{\frac{\sum (z_{ij} - M_{id})^2}{n}}$: **Standard Deviation** of indicators for Municipality i .
- $cv_{id} = \frac{S_{id}}{M_{id}}$: **Coefficient of Variation**, used as a weighting factor for the penalty.

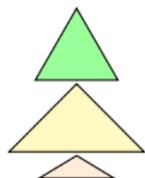
Methodological Insight

The MPI "corrects" the average by subtracting a value proportional to the internal instability of the indicators.

Comparative Visual Insight: Expected Impact by Domain (Mean Index)

Sustainability

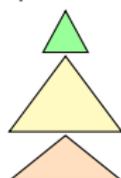
Mobility: 47%
Top Rank: 23%



"Upward Push"

Attractiveness/Accessibility

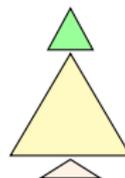
Mobility: 36%
Top Rank: 15%



"Selective Recovery"

Wellbeing

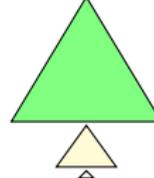
Mobility: 46%
Top Rank: 15%



"Gradual Evolution"

Digitalization

Mobility: 80%
Top Rank: 48%



"Full Convergence"

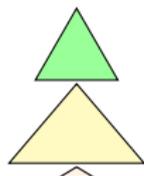
Statistical Consistency

- **Identical Peaks:** Both *Attractiveness* and *Wellbeing* show that only **15%** of Municipalities reach the top rank, despite different internal mobility dynamics (36% vs 46%).
- **The Digital Gap:** The **48%** top rank in Digitalization is more than triple the social/attractiveness domains, highlighting where the most immediate transformation is expected.

Comparative Visual Insight: Expected Impact by Domain (MPI Index)

Sustainability

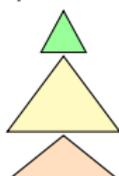
Mobility: 60%
Top Rank: 23%



"Strong Upward Push"

Attractiveness/Accessibility

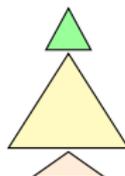
Mobility: 37%
Top Rank: 15%



"Selective Recovery"

Wellbeing

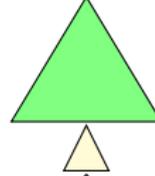
Mobility: 47%
Top Rank: 15%



"Gradual Evolution"

Digitalization

Mobility: 89%
Top Rank: 48%



"Full Convergence"

Key Observations on New Data

- **Sustainability Leveling:** With 89% positive mobility in Digitalization and 60% in Sustainability, the PNRR is perceived as a powerful tool to eliminate structural gaps.
- **The 15% Threshold:** Attractiveness and Wellbeing remain the "bottleneck" domains, where only a minority expects to reach the absolute peak despite widespread general improvement.

Comparing Aggregation Insights

- Comparing **Mean** (Intensity) and **MPI** (Balance) confirms the 4-domain structure while highlighting different facets of PNRR impact.

1. Key Insights (Results)

- **Leading:** Digitalization shows massive convergence (89% MPI mobility).
- **Bottlenecks:** Attractiveness and Wellbeing (15% Top Rank) remain selective.

Analytical Shift

*MPI rankings are chosen for the following group analysis as they better represent **stable municipal progress**.*

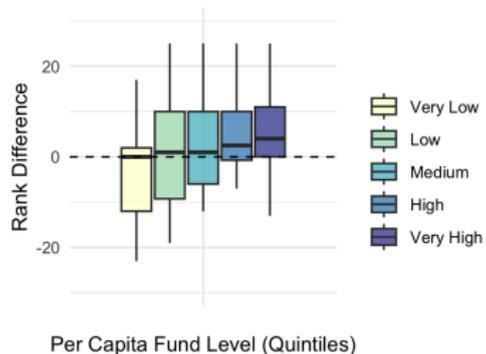
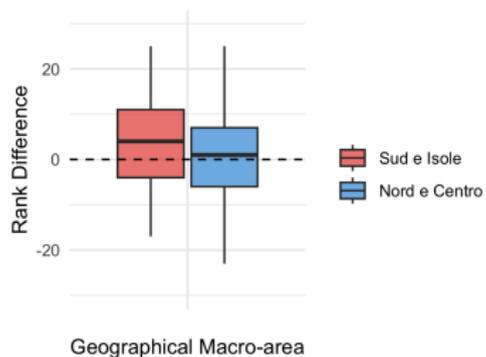
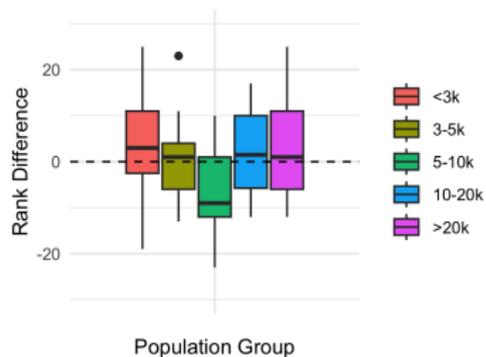
2. Robustness of MPI

- **Penalty for Imbalance:** MPI filters out "illusory" gains driven by single outlier indicators.
- **Internal Cohesion:** Higher MPI mobility proves expectations are **homogeneous** within domains.

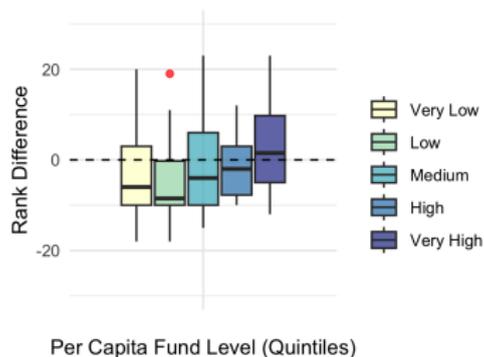
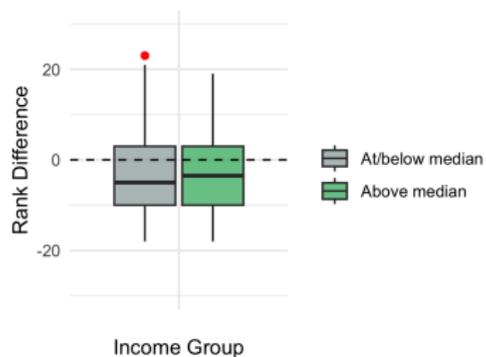
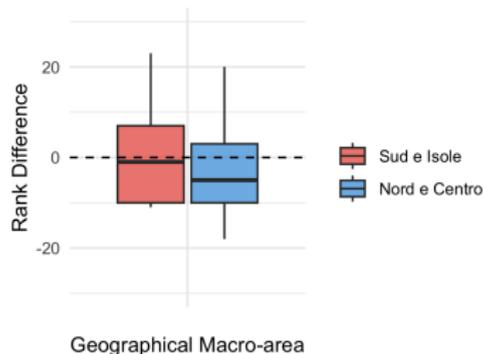
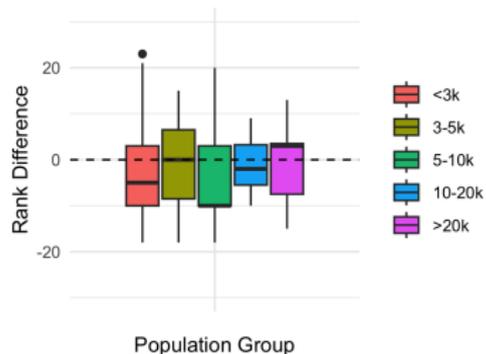
Key Justification

MPI "stresses" the pillars, rewarding balanced growth across all domain indicators.

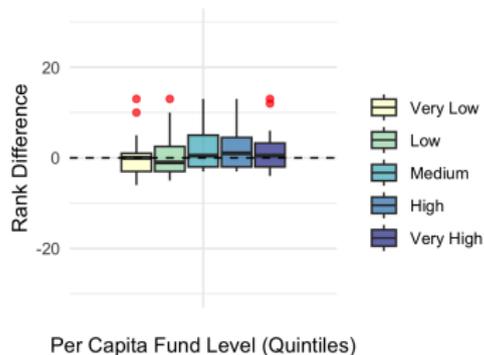
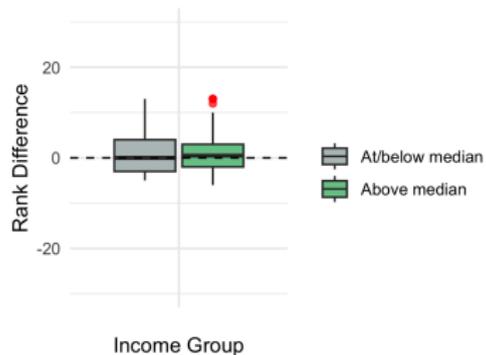
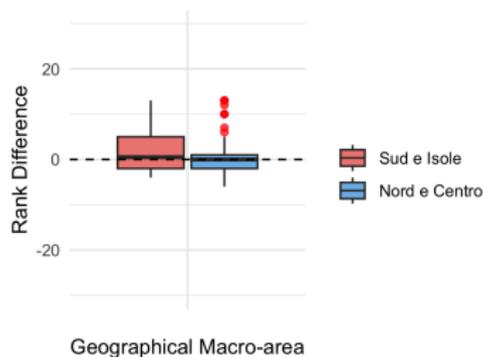
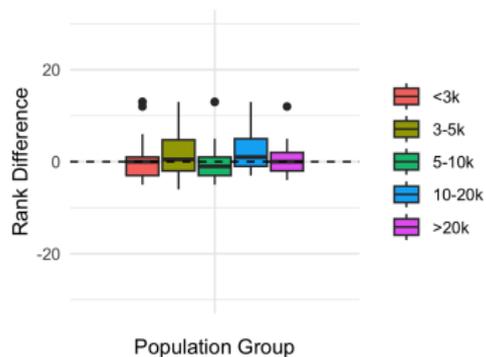
Sustainability: Comparison of Rank Differences by Group



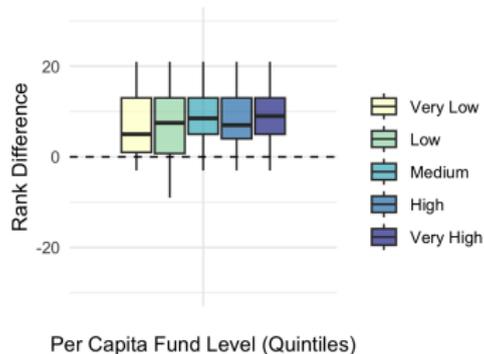
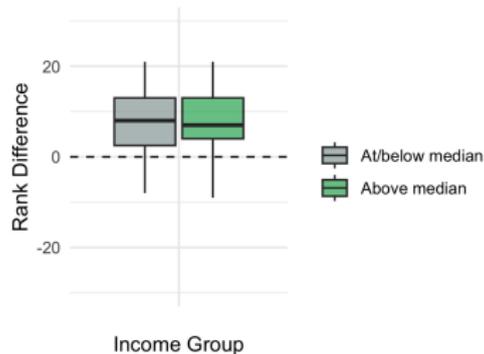
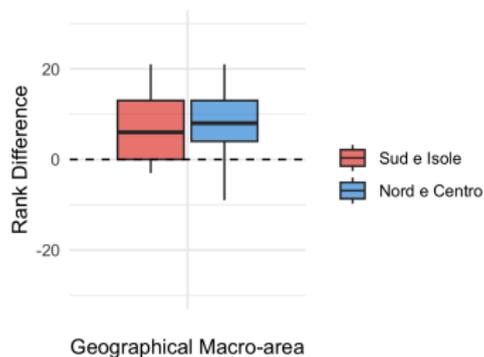
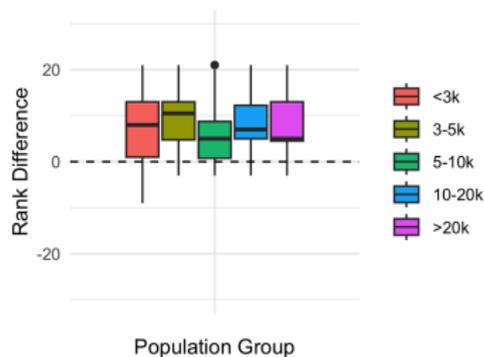
Attractiveness/Accessibility: Comparison of Rank Differences by Group



Wellbeing: Comparison of Rank Differences by Group



Digitalization: Comparison of Rank Differences by Group



MPI Analysis: Structural Trends and Rank Shifts

1. The "Small Towns" Volatility

Population Group (<3k):

- Widest distribution (whiskers) across all pillars.
- High risk of rank loss, but unique potential for **upward leaps** (> 20 positions) in Sustainability and Attractiveness.

2. Territorial Convergence

Sud e Isole vs Nord e Centro:

- **Mezzogiorno** shows higher median rank growth.
- PNRR is perceived as a **catch-up tool**, allowing Southern municipalities to scale the national ranking.

3. The Funding Lever

Per Capita Fund Level:

- Most consistent driver: a **quasi-linear relationship** between investment intensity and rank improvement.
- High-funded quintiles show the most compact and positive distributions.

4. Income & Resilience

Income Group:

- Municipalities **at/below median income** exhibit higher Rank Differences.
- Suggests PNRR impact is stronger where structural gaps are wider.

Key Takeaway: MPI rankings confirm that PNRR acts as a "Great Equalizer" for Southern and Small Municipalities, provided that funding levels are sufficient.

Final Synthesis: Drivers, Methods, and Heterogeneity

Methodology

AF + MPI Strategy: Isolated 4 pillars from noise. The **MPI** index was crucial to reward balanced growth and penalize "isolated peaks."

Domain Dynamics

Digitalization is the leader (48% Top Rank). **Attractiveness & Wellbeing** are structural bottlenecks with higher variance.

Heterogeneity

Funding Effect: Direct link between per capita funds and rank. **Small Towns:** High volatility but potential for "leaps."

The "Social" Challenge

From isolated projects to balanced performance.

- **Digital:** Primary Driver.
- **Social:** Success depends on MPI balance.

Policy Implication: PNRR impact is not uniform. Structural change is driven by Digitalization, while Social success requires balanced goal convergence.

Thank you for your attention!

Any questions?

Francesca Mariani

`f.mariani@staff.univpm.it`

Università Politecnica delle Marche