

Integrating Tourism Pressure into the Municipal Fragility Index: Evidence from the Aosta Valley

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Abstract The fragility of mountain areas has become a key issue within environmental policy, especially in light of the recent revision of mountain legislation, which highlights the need for targeted and long-term interventions to address their structural vulnerabilities. To this aim, the composite fragility index based on twelve elementary indicators developed by ISTAT summarizes socio-economic and demographic dimensions of fragility. However, further sources of territorial pressure may exacerbate existing fragility. Accordingly, by incorporating tourism intensity relative to local accommodation capacity, a novel fragility index is calculated for municipalities in the Aosta Valley. The enhanced index better identifies municipalities where tourism pressure amplifies structural fragility, thereby highlighting areas that warrant increased policy attention.

Key words: municipal fragility index (MFI) , AMPI+, Aosta Valley, tourism

1 Introduction

Mountain areas represent some of the most complex and vulnerable territorial contexts in Italy and across Europe. While these regions are characterized by an exceptionally rich natural, landscape, and cultural heritage, they are simultaneously exposed to a wide range of criticalities that challenge their environmental, economic, and social sustainability. The development of the Municipal Fragility Index (MFI) [2] by the Italian National Institute of Statistics (ISTAT) accommodates the idea that the vulnerability of a territory is the result of a complex interplay among environmental, demographic, economic, and infrastructural conditions. In mountain municipalities, where the balance between humans and the environment is partic-

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ularly delicate, fragility takes on a systemic dimension: progressive depopulation, population aging, difficulties in maintaining essential services, and dependence on a limited number of productive sectors all contribute to reducing the overall resilience of the territory. The MFI provides a synthetic measure of the level of fragility of municipalities to identify areas most exposed to specific risk factors and facilitate the territorial analysis of the phenomenon over time. The index is constructed through the combination of twelve elementary indicators that describe the main territorial, environmental, and socio-economic dimensions of municipal fragility. The methodology used for the transformation and aggregation of the elementary indicators is based on the assumption of non-substitutability among the different components; therefore, the MFI is a non-compensatory composite index (or partially non-compensatory, Adjusted Mazziotta-Pareto Index, AMPI+) [1]. Under the assumption of non-substitutability or partial substitutability of the elementary indicators, the compensatory effect of the arithmetic mean is corrected by adding a factor that depends on the variability of the indicators for each municipality with respect to the reference values used for normalization. This methodology assigns each municipality an index value that is comparable both over time (2018, 2019, and 2021) and across territories, using the national value for Italy in 2018, set equal to 100, as the reference parameter. However, further sources of territorial pressure may exacerbate existing fragility. Therefore, this paper aims at introducing, in addition to the twelve indicators proposed by ISTAT, a thirteenth indicator. Hereafter, referred to as PRatio (Pressure Ratio) is designed to capture the intensity of tourist flows and local infrastructural capacity, highlighting how a given volume of tourists may generate very different impacts in municipalities with distinct structural characteristics. In particular, a high PRatio value indicates elevated tourism pressure relative to accommodation capacity, suggesting a potential risk of overload and territorial fragility. The analysis subsequently compares the index based on the original twelve indicators - recalculated using the Aosta Valley as the reference region rather than Italy as a whole - with the index that also incorporates the thirteenth indicator. This territory is of particular interest, as it is entirely composed of mountain municipalities even under the new mountain legislation and is characterized by a strong tourism vocation. The comparison of the two index versions enables the identification of municipalities where tourism pressure constitutes a critical driver of vulnerability.

2 Method and application

Considering the accommodation capacity of each municipality, the PRatio is defined as $\text{PRatio} = \frac{T_i}{P_i}$ where T_i is the average number of tourists in the municipality i , calculated by dividing the annual number of tourist overnight stays by 365; and P_i is the equivalent population: it measures the total number of people physically present in a municipality, combining legal residents, with temporary visitors. The latter is obtained taking into account the occupancy rate, $p = \frac{On_i}{B \times 365} * 100$, where On_i are the overnight stays in each municipality. The PRatio is then combined with the other

twelve indicators ($j = 1, \dots, 12$) used by ISTAT for the MFI. To obtain the MFI, the AMPI+ method normalizes the twelve indicators - collected in the matrix $\mathbf{X} = \{x_{ij}\}$ - according to the following formula:

$$r_{ij} = \frac{x_{ij} - \text{Min}_{x_j}}{\text{Max}_{x_j} - \text{Min}_{x_j}} * 60 + 70$$

where r_{ij} and x_{ij} are, respectively, the normalized value and the value of indicator j in municipality i . $\text{Min}_{x_j} = \text{Ref}_{x_j} - \Delta$ and $\text{Max}_{x_j} = \text{Ref}_{x_j} + \Delta$ are goalposts defined so as to set the regional value in the year 2018 equal to 100. Ref_{x_j} is the reference value for indicator j , given by the value of the indicator for Aosta Valley in 2018; $\Delta = \frac{\text{Sup}_{x_j} - \text{Inf}_{x_j}}{2}$, and Inf_{x_j} and Sup_{x_j} are, respectively, the minimum and the maximum values of indicator j in the municipal distribution across all periods considered. The resulting values fall approximately within the range (70; 130), where 100 represents the reference value (regional average in 2018). The composite index is then obtained by aggregating the normalized indicators with equal weights using the simple arithmetic mean. The synthetic index of the i -th unit is subsequently obtained by applying, with a positive penalty, the corrected version of the penalty method based on the coefficient of variation (AMPI+):

$$\text{AMPI+} = M_{r_i} + S_{r_i} \times cv_i, \quad \text{with} \quad cv_i = \frac{S_{r_i}}{M_{r_i}}$$

where M_{r_i} , S_{r_i} and cv_i are the mean, the standard deviation and the coefficient of variation of the normalized indicators value, respectively.

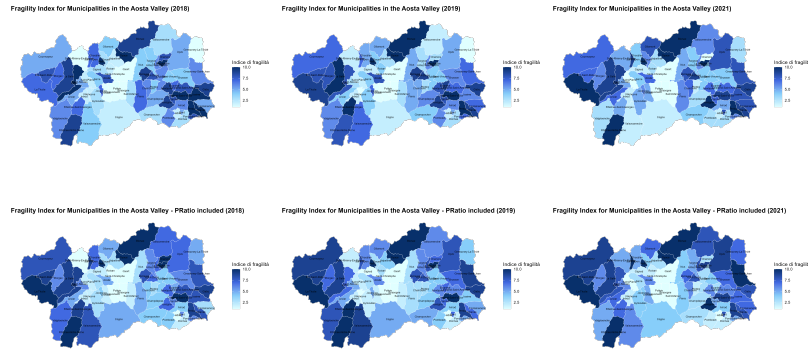


Fig. 1: Aosta Valley MFI calculated using indicators adopted by ISTAT (1st row) and including the PRatio indicator (2nd row). Areas with darker shades indicate higher levels of fragility. Results refers to the years 2018, 2019, and 2021.

Fig. 1 (1st row) presents the MFI for each municipality, computed using the twelve indicators, while Fig. 1 (2nd row) shows the MFI calculated with the inclusion of the PRatio indicator. Fig. 2 illustrates the difference between the MFI calculated with thirteen (Fig. 1, 2nd row) and twelve indicators (Fig. 1, 1st row). It is worth noting that, incorporating tourism pressure into the fragility index allows for the identification of territorial contexts in which tourism acts as a mitigating factor (shades of green) versus those in which it constitutes a source of increased vulnerability (shade of red), thereby providing an informative tool for the design of sustainable and differentiated territorial management policies.

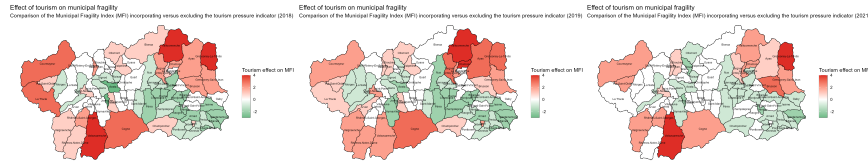


Fig. 2: Difference between the MFI based on 13 indicators (including PRatio) and on 12 indicators - years 2018, 2019, 2021. Shades of red indicate municipalities with increased fragility when tourism is included while shades of green suggest where fragility is mitigated by the additional indicator.

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