POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Modelling Short-term Resilience: An Empirical Exploration of Italy's Response to the COVID-19 Pandemic

Tesi di Laurea Magistrale in
Management Engineering - Ingegneria Gestionale

Author: **Filomena Barbieri, Chiara Buttelli**

Student ID: 989883, 992443
Advisor: Prof. Giovanni Azzone
Co-advisors: Prof. Marika Arena
Academic Year: 2022-23

Abstract

This thesis focuses on analysing short-term resilience in Italy in the face of the impact of the **COVID-19 pandemi**c. **Short-term resilience** refers to a region's ability to bounce back from sudden shocks by making adaptive adjustments to its economic, social and institutional structures. It includes two primary aspects: **Resistance**, measuring a region's initial sensitivity to disruptions, and **Recovery**, assessing how quickly and effectively the region can restore its previous performance.

The main objective of this study is to gain a deeper understanding of how different Italian provinces have coped with the COVID-19 disruption and what factors have influenced their capability for immediate Resistance and Recovery. The approach is **multidimensional** and takes into account social, economic, and environmental determinants in order to explain territorial variations in the labour market dynamics triggered by the pandemic shock.

The results reveal that short-term regional resilience cannot be simplistically attributed to geographic location or economic structure but rather emerges as the result of a complex interplay of local factors. While some of these factors are relevant to both Resistance and Recovery, each phase of the resilience process is shaped by a unique set of determinants. This underscores the importance of developing tailored strategies to strengthen the capacity of regional economies to respond to and recover from unexpected disruptions.

The research provides a theoretical contribution to the understanding of resilience, helping to outline a comprehensive definition for a concept still subject to academic debate. Furthermore, a quantitative model that assesses resilience and applies it concretely to Italian provinces is presented.

The practical implications of this analysis are of significant importance for policymakers and stakeholders, as strategies derived from these findings can trigger promising sustainable economic growth and enhance Italy's adaptability in anticipation of future challenges.

Keywords: Resilience, Short-Term, COVID-19 Pandemic, Recovery, Resistance, Linear Model.

Abstract in lingua italiana

Questa tesi presenta i risultati di uno studio sulla resilienza a breve termine alla pandemia di **COVID-19** in Italia. Con **resilienza a breve termine** si intende la capacità di una regione di riprendersi a tempi brevi da uno shock che la colpisca, adattando la propria struttura economica, sociale e istituzionale. Si compone di due aspetti principali: la **Resistenza**, connotata dalla la sensibilità iniziale della regione alla perturbazione esaminata, e la **Ripresa**, che valuta la rapidità e l'efficacia della regione nel ripristinare le proprie prestazioni ai livelli precedenti allo shock. L'obiettivo ultimo è analizzare la risposta delle diverse province italiane alla Pandemia e di indagare quali fattori ne abbiano influenzato la capacità di Resistenza e Ripresa immediata. Per identificare le dinamiche di risposta locali in termini di variazione del mercato del lavoro, si adotta un approccio **multidimensionale**, incorporando determinanti di natura sociale, economica ed ambientale.

I risultati hanno dimostrato come la resilienza a breve termine non possa essere meramente attribuita alla posizione geografica o alla struttura economica della regione, ma sia risultato di una complessa sinergia di fattori. Se alcuni di questi risultano rilevanti sia per la fase di Resistenza sia per quella di Ripresa, altri sono specifici di una delle due, denotando come ciascuna fase sia plasmata univocamente da un set di determinanti puntuali. Ciò enfatizza l'importanza dello sviluppo di strategie mirate a rafforzare la capacità delle economie regionali di reagire e riprendersi dalle perturbazioni.

Questa ricerca fornisce un contributo teorico alla comprensione della nozione di resilienza, impegnandosi a delineare una definizione esaustiva per un argomento che è ancora oggetto di dibattito accademico. Inoltre la tesi, tramite la costruzione di un modello quantitativo, sviluppa un'analisi empirica tesa a valutare le determinanti di resilienza e la loro manifestazione nel caso italiano. Le implicazioni del modello possono essere considerate come spunto di riflessione per le strategie d'azione di decisori politici e stakeholders in generale: potrebbero rivelarsi utili catalizzatori di una solida crescita economica in Italia, rafforzando la capacità di adattamento in previsione di sfide future.

Parole chiave: Resilienza, Breve termine, Pandemia di COVID-19, Ripresa, Resistenza, Modello lineare.

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Executive Summary of the Thesis

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1. Introduction

Originally grounded in the realms of physical-mechanical science and psychology, the concept of **resilience** has recently evolved into a versatile notion spanning ecology, crisis management, and urban planning, with the aim of expressing the inherent capacity of any system to effectively respond to and rebound from shocks. This dissertation centres on the examination of the intricate interplay between resilience and socio-economic dynamics within regions, herein referred to as **regional economic resilience**.

At the heart of this exploration lies the fundamental premise that diverse patterns of resilience directly shape disparate **economic growth trajectories** across regions [2, 4]. Historical evidence reveals that disruptions impact regions uniquely, emphasizing the pertinence of resilience in comprehending these diverse reactions.

The focus revolves around the study of **short-term** resilience. This temporal framework provides valuable insights for crisis decision-making, enabling policymakers to swiftly adapt their strategies and potentially mitigate the crisis's impact [6]. This not only aids in immediate disruption response but, in turn, informs long-term planning, fostering a more adaptable and comprehensive approach to resilience-building over time. Additionally, short-term research reveals the psychological and societal responses to crises, shedding light on how individuals and communities mobilize resources in times of adversity. Hence, this focus serves as a vital means through which to observe the **agility** and **adaptability** of systems when confronted with unforeseen challenges.

2. Relevance of the topic

The sequence of consecutive crises and environmental upheavals of the last decades has triggered a dedicated exploration into the multi-faceted drivers behind the contrasting rates and expenses of recovery in the short term. The deepening sense of **insecurity** and **vulnerability** experienced by recent generations in the face of unforeseen events has further accentuated the growing prominence of the resilience notion. Coupled with a **transforming global landscape**, the perception of heightened risk exposes regions to greater susceptibility to external influences [3]. These evolving perceptions amplify the call for methodical strategies tailored to enhance the readiness of both societal

and economic stakeholders.
In addition, the recent global spread of the **COVID-19 pandemic** has brought a spotlight to bear on the very topic under discussion. The Pandemic's far-reaching effects extend beyond the tragic loss of lives and widespread health concerns, sparking an unprecedented **economic crisis** with consequences that are still unfolding. The immediate response of governments worldwide to contain the virus through stringent **lockdown measures** led to a virtual halt in economic activities, setting the stage for a looming, sustained employment downturn, particularly impacting vulnerable groups. This crisis has prompted critical reflections on prevailing **organizational methods**. A pivotal concern is the ongoing emphasis on productivity, which, if not seamlessly aligned with the capacity to navigate disruptions, may yield unfavourable outcomes. The Pandemic has emphasized the crucial need for increased **adaptability** in local economies, highlighting the intrinsic importance of **redundancy** over mere efficiency in sustaining overall system functionality. In essence, due to the recurring and endemic nature of shocks, while the pursuit of long-term regional progress and growth remains undeniably significant, greater emphasis must be placed on short-term shock management.
Moreover, the Pandemic has revealed preexisting weaknesses within many economies, particularly those stemming from the aftermath of the 2008 financial crisis [1]. As economies navigate the challenges of a sluggish recovery from the previous recession, the unique character of the current economic shock necessitates innovative policy actions and state interventions to stabilize businesses, preserve employment, and enhance overall well-being. Initiatives like **NextGenerationEU** have emerged, indicating a **paradigm shift** in policy approaches and public investments [1] To conclude, this COVID-19 disruption presents an exceptional **opportunity** to examine the resilience conceptual framework and glean a promising perspective for understanding how economic systems can intentionally build robust structures to manage shocks effectively.

3. Objectives of the thesis

The final objective is to study the determinants of short-term resilience, answering the following research questions:

- **RQ1**: "Which specific factors have played a pivotal role in shaping the diverse responses to the COVID-19 crisis across distinct provinces in Italy?"
- **RQ2**: "Given these factors, what actionable insights can be derived to guide effective policy-making and strategic planning aimed at enhancing short-term resilience in this context?".

In order to address these inquiries, it was necessary to clarify the research's scope in advance, delineating three distinct dimensions of analysis: resilience *to what* kind of shock, *of what* geographical area and *over what period*.
Given its significance, the research will centre on resilience to **COVID-19 pandemic**. Despite the global repercussions of the Pandemic, the study will deliberately confine its examination to the **Italian territory**: this approach avoids overgeneralization, allowing for a more focused understanding of territory-specific dynamics. The analysis operates at a provincial (NUTS3 units) level, striking a balance between granularity and manageability. Finally, the choice of an **annual time bucket** and a time horizon spanning from **2018** to **2022** is dictated by data availability and the contemporaneity of the shock. Including the years 2018 and 2019 serves as a baseline, providing insight into the economic conditions preceding the shock. This timeframe covers Italy's critical pandemic period, including infection spikes, various containment measures and initial recovery efforts.
Answering the research questions requires a **quantitative methodology**, which bridges the existing literature gap by reaching a comprehensive understanding of the short-term determinants of regional resilience that encompasses the full spectrum of social, economic and environmental dimensions.
A **regression model** will be developed to capture the influence of the selected determinants on the Italian response to COVID-19, modelled through **synthetic measures** grasping the fluctuations of the labour market.
In light of these findings, it is possible to draw some observations regarding the allocation of resources provided through the PNRR [1], deeply investigating Italy's overall performance and preparedness for potential adversities.

4. Methodological Approach

The research methodology addresses three major phases: **Literature Review**; **Model Development** and **Model Validation**.

[1] National Recovery and Resilience Plan

4.1. Literature Review

Considering the topic's maturity, the most suitable approach was to start by conducting a **comparative analysis** of the various literature contributions. The aim was to achieve a **comprehensive definition** of regional economic resilience. Databases such as **Scopus** and **Web of Science** played a pivotal role in source selection. Additionally, the **snowballing method** was employed, starting from exemplary literature, to expand knowledge and develop critical thinking.
When delving into the analysis of resilience determinants adopted in the literature, it was essential to examine a wide set of diverse studies, assessing different types of shocks, locations and timeframes. This holistic analysis highlighted the unique characteristics of different regions' responses to shocks, allowing for the identification of differences and commonalities among them. This led to the creation of a **comprehensive table** categorizing resilience indicators, based on different **areas**, **macro-areas** and **dimensions**.

4.2. Model Development

The **model development** phase encompassed the definition of the **synthetic measures** of short-term resilience and the construction of a **dashboards** of their **determinants**, through the selection of the relevant areas from those identified in the literature review. This selection method involved two distinct steps: a **scoring criterion**, taking into account a set of evaluation factors, and a **critical analysis**, to provide further rationale and diminish the number of selected determinants.
For each of the selected determinants, an iterative **data collection** process was conducted to choose the most suitable indicator and its corresponding metric, taking into account constraints related to the availability of provincial data obtainable from publicly accessible sources.

4.3. Model Validation

Finally, the methodology concerning the model validation primarily revolves around the construction of the **regression model**, embracing the principles of ordinary least squares (OLS) estimation to unveil the best-fitting line that encapsulates the interplay between independent and dependent variables of the study. The progressive refinements of the model code that led ultimately to the identification of significant variables encompassed a first phase of **collinearity management** and a last phase of **variable selection** made through t-test statistics and validated through a *step-wise selection*.

5. Comprehensive Definition of Resilience

The historical development of the resilience notion revolves around four distinct definitions, namely **Engineering**; **Ecological**; **Adaptive** and **Transformational** resilience [4]. While ecological and engineering definitions have long-established foundations, the introduction of the latter marked a pivotal break from the **equilibrium** cornerstone: unlike ecological or physical-engineering systems, which can reach equilibrium if left undisturbed, economic systems remain in constant flux, adapting to evolving economic contexts driven by knowledge development, acquisition, and commercialization.
However, efforts to converge these diverse definitions towards a shared understanding reveal that they are not entirely distinct. **R. Martin** was capable of encapsulating the essence of resilience into a singular comprehensive notion: "the capacity of a region to withstand or recover from shocks to its developmental growth path, if necessary by undergoing adaptive changes to its economic structures and its social and institutional arrangements, to maintain or restore its previous developmental path, or transit to a new sustainable path characterized by more productive and equitable use of its physical, human and environmental resources" [6].
Furthermore, the same author identified four temporal phases of resilience: **Resistance** and **Recovery** in the short-term; **Re-orientation** and **Renewal** in the long run. These dimensions' interplay influences a region's vulnerability, capacity to rebound, adaptability and ability to resume growth paths [1, 4, 5].
Considering the objectives, this thesis naturally focuses only on the Resistance and Recovery phases, with the computation of two respective indices to synthetically measure short-term resilience.

6. Model Development

6.1. Short-term Resilience Synthetic Measures

In order to construct a **Resistance index** and a **Recovery index**, it was essential to identify a phenomenon for observation that reflected the overall response of the examined region to the shock. The literature exploration has underscored the prominence of the **employment rate** and **output rates** (e.g., GDP) as key explanatory factors for gauging regional economic resilience in a synthetic manner. The decision between these two paths for constructing the indices ultimately leans toward utilizing the **employment rate**, aligning with both theoretical and practical reasoning further explored within the thesis.
Resistance is quantitatively assessed by using the **Sensitivity Index** *à la Martin*, by comparing the

relative changes in employment levels between a specific province and the nation as a whole for the shock-year ($t_1 = 2020$ and the pre-shock year $t_0 = 2019$).

$$\text{SI} = \frac{\Delta E_p(t_1, t_0)}{\Delta E_n(t_1, t_0)}$$

The **Recovery Index** assesses the provinces' speed to restore the pre-shock level of employment (at $t_0 = 2019$). It is computed by averaging the Recovery achieved in 2021 - i.e. the difference between the employment level delta for 2021-2019 and the employment level delta for 2020-2019 - and the Recovery achieved in 2022 - i.e. the difference between the employment level delta for 2022-2019 and the RI_{2021}.

$$\text{RI} = \frac{RI_{2021} + RI_{2022}}{2}$$

6.2. Short-term Resilience Determinants

Exploring the determinants of the aforementioned indices, the literature review led to the following categorization of resilience indicators:

- **Social dimension**
  - Community well-being
    - Social fragility
    - Social cohesion
    - Social integration
    - Psychological factors
    - Health
  - Community composition & development
    - Demographics
    - Population change
  - Service availability
    - Social services
    - Health facilities
    - Digital opportunities
  - Human capital
    - Competencies
    - Digital skills
- **Environmental dimension**
  - Pollution
    - Air pollution
    - Water pollution
  - Natural hazards
    - Seismic risk
    - Hydrogeological risk
  - Natural resources
    - Soil condition
    - Nature capital
  - Waste
    - Waste sorting
- **Economic dimension**
  - Firms
    - Financial solidity
    - Entrepreneurship
    - Competitive profile
    - Innovation
    - Diversification vs. Specialization
    - Agglomeration economies
    - Trade dynamics
  - Infrastructures
    - Connectivity & access to digital network
    - Access to energy network
    - Access to transportation network
  - Institutions
    - Governance arrangements
    - Financial condition
    - Safety

This framework provided a robust basis for the deliberate **selection** of the most relevant determinants of Resistance and Recovery within the specific context of this thesis. By means of the previously mentioned two-step methodology, the chosen determinants of short-term resilience integrated into the model are:

- Social fragility;
- Population change;
- Health facilities;
- Digital opportunities;
- Competencies;
- Seismic risk;
- Soil condition;
- Waste sorting;
- Innovation;
- Diversification;
- Agglomeration economies;
- Connectivity & access to digital network;
- Access to transportation network;
- Financial condition.

7. Model Validation

Once all essential components were assembled, the development of two parallel linear regression models — one for Resistance and another for Recovery — constituting the core of this thesis exploration, was initiated. The mathematical definition of these models takes the following form:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_p X_{pi} + \epsilon_i$$

Where:

- Y_i is the **response variable**, namely the SI or the RI for NUT3 area i;
- $X_{1i}, X_{2i}, \ldots, X_{ji}$ represent the selected j **independent variables**, i.e. the selected short-term resilience determinants;
- β_0 is the **intercept term**;
- $\beta_1, \beta_2, \ldots, \beta_j$ embody the **slope coefficients**;
- ϵ_i encapsulates the **irreducible error**.

8. Results & Findings

Looking at the **Recovery Index**, the provinces exhibiting more pronounced recovery appear to be concentrated in the **southern regions** of Italy. This

phenomenon could stem from the fact that the onset of COVID-19 reached the southern areas with a **delay** compared to the northern regions, thus allowing the provinces in the South more time to restructure their assets in preparation for tackling the Pandemic. Consequently, these provinces, if not experiencing a milder shock (higher Resistance), at least managed to recuperate at a swifter pace (higher Recovery). However, it is worth noting that the South's superior Recovery may be partially due to a resilience synthetic measure based primarily on employment levels, which are typically lower and more inflexible in the South and may therefore show less pronounced alterations in the face of negative shocks. Shifting now the focus to the distribution of **Resistance** levels across Italy, while it is evident that both the North and the South have provinces with varying levels of resilience, this analysis shows that there is no consistent pattern of one region consistently outperforming the other. This reaffirms that the Pandemic's impact on employment was not solely determined by geographical location and emphasizes once again the importance of identifying the specific local factors that drive regions' performances in front of shocks. However, in northern provinces, the Resistance index tends to be more **homogeneous** compared to the southern regions. This likely reflects the fact that the outbreak began in the North, which had less time to prepare and diversify its response. On the contrary, provinces in the South generally displayed a wider range of reactions, with notable resistance peaks in Sicily. In general, the overall trend indicates a **weak correlation** between Resistance and Recovery that underscores the significance of **locally executed measures** within each province. This highlights that a comprehensive response at a broader administrative level (regions) that enables such overarching strategies needs to be integrated with tailored actions at a granular local level (within provinces), to address the distinct economic landscapes, infrastructural nuances, and existing status quo within each smaller administrative entity.

Turning to the results brought about by the significance of the model's independent variables, from the parallel examination of the two linear regression models, an intriguing observation emerges: while certain indicators contributing significantly to the Resistance dimension also appear within the set of indicators impacting Recovery, the reverse is not found to be true. This **divergence** prompts consideration of the dynamics at play. It is plausible that factors that hold pronounced importance in the immediate aftermath of the shock (thus determining high Resistance) continue to wield a lasting influence during the subsequent years of restoration. In contrast, during the Recovery phase, a new spectrum of indicators comes into play. This nuanced distinction may arise from the **temporal dimension**. Some factors that distinctly differentiate one geographical area from another might reveal their effects only when considered over a slightly broader time horizon. Such factors could be somewhat "muted" precisely at the moment of the shock's occurrence and its immediate aftermath, owing to their impact gaining prominence with time.

Analyzing the Resistance regression model on its own, the results underscore the significance of the following aspects:

- the importance of revitalization and heightened appeal of the regions to reduce to mitigate **internal migratory flow**;
- the necessity of a facilitated and **stable financial state for local institutions**, which need to establish financial reserves stands as a means to mitigate vulnerabilities;
- the cultivation of a **diversified** and **adaptable economy** responsive to market shifts, while reducing dependency on specific susceptible industries;
- lastly, on a more profound level, the criticality of well-crafted policies to address **social fragility** and provide assistance to the most vulnerable.

Moving to **Recovery** singular analysis, the research provided substantial evidence of its multidimensional nature. In fact, the number of relevant factors increases while their impact on the response variable diminishes. Hence, this underscores:

- the significance of **innovativeness**, which holds pivotal importance in a rapidly evolving global landscape;
- the critical need to accord proper prominence to **connectivity** in contemporary times to avoid being left behind;
- the relevance of a **cohesive hospital** and **social care infrastructure** that unifies the country rather than perpetuating division into two distinct *Italies*;
- the **potency of urban node connections**, alongside the imperative of ensuring that peripherical areas are not cut off;
- eventually, the consciousness that the recovery capability, thus resilience, derives strength from previous trials, particularly evident in regions that have confronted challenges such as the heightened risk associated with **seismic activity**.

  In essence, the concept of resilience is confirmed as an intricately woven and profoundly **multidisciplinary** notion. Despite a primary focus on economic facets, its essence necessitates a broader perspective - evident in the determinants that have proven to be significant.

9. Conclusion

In conclusion, this thesis offers its contribution to the understanding of resilience from different perspectives.
Firstly, a significant contribution of this thesis lies in its endeavour to clarify the concept of short-term resilience. Specifically, it offers a comprehensive assessment of the definitions of regional economic resilience found in the literature. This effort goes beyond a mere review of definitions: it extends to the assertion that the concept of **equilibrium** should be discarded as a foundational measure of resilience. On the contrary, the importance of perceiving resilience as an **evolutionary process** is emphasized, with equilibrium considered merely as a tool for modelling and index construction. This approach aligns with the most recent and comprehensive definition attributed to Martin.
Furthermore, this study goes beyond theoretical considerations and offers a **systematic procedure** for identifying the short-term determinants of regional economic resilience. It provides a contribution by **categorizing resilience indicators** into areas and macro-areas within the dimensions of social, economic, and environmental resilience.
The culmination of the efforts is the development of the **Resistance and Recovery measurement models**, which, while applied to Italy during the COVID-19 pandemic, offer foundational insights applicable to similar contexts.
However, it's crucial to acknowledge the limitations of this research, including **data availability** constraints, **sample size** considerations, and the discretionary **pre-modelling** selection of resilience areas. Additionally, the study's **temporal scope** is limited, and future research is encouraged to explore resilience over longer periods and investigate subsequent phases of resilience.
Despite these limitations, this thesis provides valuable insights into the complex and multidisciplinary nature of regional economic resilience, laying the foundation for future studies and policy initiatives aimed at enhancing resilience in various contexts.

10. Bibliography

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Acknowledgements

The authors wish to express their gratitude to Professor Giovanni Azzone and Professor Marika Arena for their attention, availability and invaluable support throughout the development of this thesis.
A heartfelt appreciation is extended to Politecnico di Milano, the academic institution that has fostered their educational journey.
On a personal note, the authors would like to extend their gratitude to their families and friends. Their unwavering support throughout this path has been a source of strength, encouragement and inspiration.

Contents

Introduction

The term *resilience* comes from the Latin "resilire", literally "to jump back" or "to return back". It has been introduced in the physical-mechanical field to describe the ability of a body to absorb energy and return to its original shape after being subjected to elastic deformation. Another classic field of application of the term is the psychological field, where it takes on the meaning of overcoming a situation of disruption by recovering to one's initial state or, according to a more dynamic perspective, the process of coping with adversity by concluding with individual improvement and fortification.
Over time, the concept of resilience has been extended to different realms, notably ecology, crisis management and urban planning, and it has acquired a broader meaning, referring to the ability of a system of any kind to react and recover from a crisis.

The purpose of this thesis is to investigate the realm of economic resilience applied to the context of a region experiencing a shock, referred to as "**regional economic resilience**". Although not a recent topic, regional economic resilience has gained prominence in the very last years. While the focus on regional economic growth historically revolved around the convergence speed of per-capita incomes, contemporary research has turned the attention to analysing resilience's variations throughout time, aiming to understand the reasons behind the differences between regions. Indeed, even though the debates on the applicability of neoclassical growth theory and the emergence of the so-called "endogenous growth theory" in the 1980s and 1990s have paved the way for numerous cross-sectional regression methods to estimate an average speed of convergence [52], the more recent investigation into the impact of significant shocks on short-term reactions and long-term regional growth patterns seems particularly fascinating.

In particular, **short-term resilience** has attracted significant attention due to its dynamic and immediate nature. In fact, short-term time horizon studies provide a window into the agility and adaptability of systems and communities in the face of unexpected challenges, capturing an aspect that is not as readily discernible when concentrating solely on long-term resilience. These studies offer real-time insights into how organizations innovate and respond rapidly to crises, shedding light on the human capacity for creative problem-solving under pressure.

Hence, the focus here is on the application of the notion of resilience to socio-economic systems, exploring the realm of regional economic resilience under a short-term perspective to uncover why regions react in different ways to exogenous shocks and how such disturbances alter their

development paths. In other terms, the basic idea is that different resilience behaviours are the reasons why regions within a country show different economic growth performances [52, 90].

In fact, economies have always been subject to significant disruptions: political changes, economic crises, environmental disasters, conflicts, pandemics and similar. These shocks rarely affect the economic landscape uniformly, often displaying unequal consequences across urban and rural, local and regional economies.

In this regard, the notion of economic resilience is highly relevant for analysing the differential reactions of regions and localities to shocks. Although not immune to theoretical and empirical criticism, this concept has emerged as a promising conceptual umbrella with the aim of explaining how economic systems can achieve a sustainable configuration to cope with disruptions [48]. As a result, the notion of economic resilience has gathered the interest of several scholars following stimuli of various sorts. Notably, the succession of crises of different and interrelated nature and environmental disasters has triggered an interest in investigating the underlying reasons for different speeds and expenses in recovering from such situations of emergencies, making the concept of resilience rapidly become part of the conceptual and analytical lexicon of regional and urban economic studies [92].

Analysing the time trend of publications concerning the topic of regional economic resilience, it can be seen in Figure 1 that a high momentum of studies was gathered following the economic crises that characterised the past decades, with a particular accent on the Great Recession of 2008. The latter's uneven consequences, both within and between countries, have given policymakers new problems to deal with, particularly when developing policies that can aid regions in recovering from the severe, protracted crisis and maintaining inclusive growth.

This rising popularity of the topic might be attributed to the widespread sense of **insecurity** and vulnerability anchored in the minds of recent generations as well as the rising sense of risk associated with globalization, which has made regions more susceptible to the effects of processes previously regarded to be external [86].

These perceptions call for a methodical investigation for new steady solutions to enhance the preparation and responsiveness of social and economic actors in the short term. In this regard, the notion of regional economic resilience is gaining fast **political traction**. Resilience is currently emerging as a key policy objective with the intent to build and improve regional economic resistance to change. The growing interest and fascination in this area are evidenced by the ready acceptance of the resilience concept by a wide range of national and international bodies and institutions, from national governments and local economic development agencies to the OECD and the European Union. The latter, for example, has emphasised the importance of relying on the resilience approach to support innovation strategies and inclusive growth in European regions (EU 2017) [37].

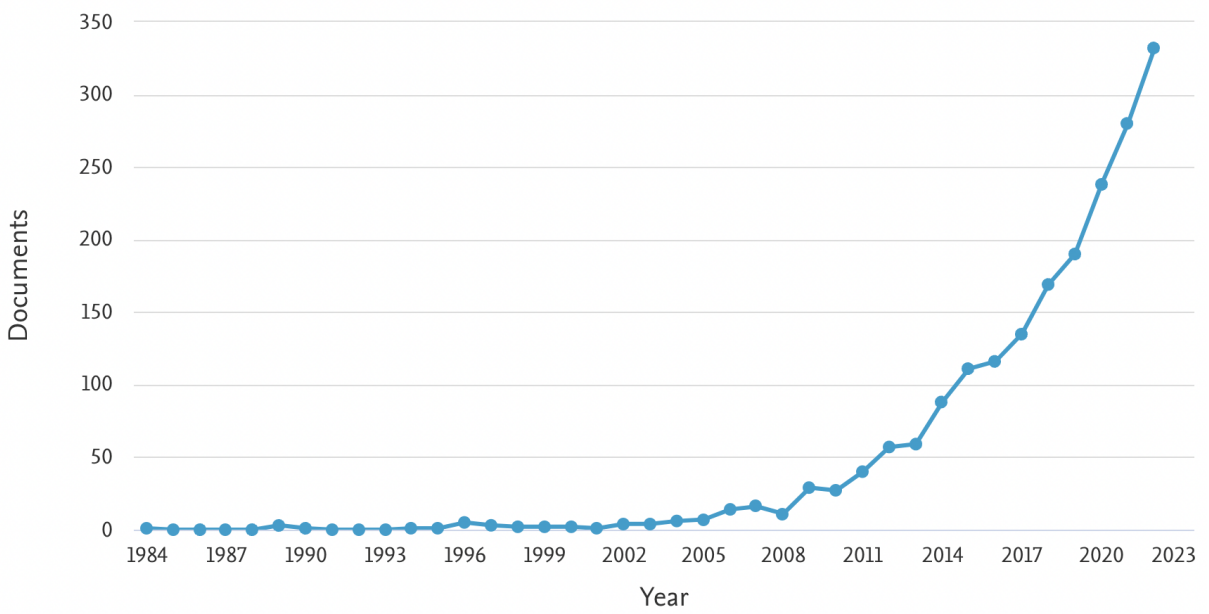

Figure 1: Number of publications per year on the topic of regional economic resilience via Scopus search.

Moreover, the recent global spread of the **COVID-19 pandemic** keeps the spotlight on the topic under discussion. The Pandemic has not only led to casualties and social problems, an unprecedented global economic recession, the disruption of global supply chains and other disruptions to our societies, but it has also created important questions about today's methods of organisation. An important question concerns the widespread emphasis on **productivity**, which can be detrimental if it is not balanced with the ability to respond to crises. The COVID-19 pandemic has highlighted the need for greater resilience and flexibility in local economies. For instance, many countries have reorganised their health systems to maximise efficiency, but this may have undermined the ability of these countries to cope with the Pandemic and its economic consequences [48]. From this experience, it was understood how redundancy, intended as opposed to efficiency, can sometimes be crucial for the system's well functioning. Similarly, the celebrated productivity advantages of large agglomerations fostering innovation, collaboration, specialisation, reduced operating costs and access to a wide range of resources, may be offset by the dramatic spread of the COVID-19 pandemic in large and concentrated industrial areas [11].

On the other hand, the implementation of other efficiency-enhancing tools, mostly related to the domain of new technologies and ICT, proved crucial during the crisis to prevent the complete freezing of activities and communications that required contact between several people or that asked for mobility. Hence, such instruments enhancing productivity can be said to have strengthened resilience when used, contrary to the aforementioned ones [48].

In conclusion, although the investigation of long-term progress and growth is of undoubted importance, to truly comprehend and influence emergencies' implications in the long run, much

attention should be paid to regions' short-term capabilities to cope with them. Indeed, shocks are recurrent and endemic, and analysing the response to them in the short term is neither trivial nor of little importance. Keynes said "*The long run is a misleading guide to current affairs. In the long run, we are all dead. Economists set themselves too easy, too useless a task if in tempestuous seasons they can only tell us that when the storm is past the ocean is flat again.*" [81]. In addition, short-term resilience research is highly **policy-relevant**, as it directly informs timely decision-making during crises. Policymakers can use these insights to adjust strategies on the fly, potentially mitigating the impact of a crisis more effectively. Consequently, short-term studies offer a unique opportunity to learn from immediate responses and crisis-specific dynamics, capturing nuances that may be lost in long-term analyses. They delve into the psychological and societal impacts of a crisis, revealing how individuals and communities come together and mobilize resources in times of adversity. These insights can then feed into long-term planning, contributing to a more comprehensive and adaptable approach to resilience-building over time.

1 | Theoretical Background

1.1. Defining Regional Economic Resilience

This chapter will focus on providing a precise definition of regional economic resilience, elucidating the key dimensions of analysis and providing a critical appraisal of the literature on the theme. The exploration will encompass an in-depth examination of resilience both in the short term and the long term, an analysis necessary to fully understand its nature and appreciate its distinctions.

1.1.1. Overview of Literature Definitions

One preliminary definition of regional economic resilience is provided by Foster [53], who defines regional resilience as "the ability of a region to anticipate, prepare for, respond to and recover from a disturbance"; emphasising the existence of two often overlapping phases, a resilience preparation phase and a performance phase.

Again, Hill, Wial and Wolman [72] conceive regional economic resilience as “the ability of a region to recover successfully from shocks to its economy that either throw it off its growth path or have the potential to throw it off its growth path but do not”.

However, it is not entirely clear what the authors mean by "recover from a shock". The ambiguity of the several definitions of resilience lies mainly in the specific connotation to be attributed to the term resilience around the notion of **equilibrium**. Equilibrium refers to a state of balance or stability in a system or economy. It is, therefore, necessary to define whether resilience refers to the ability of a regional economy to maintain its structure and function despite the disruption, or to the ability of a region or urban system to rapidly and successfully change its structure and function in response to said disruption. In the first scenario, recovery is to be understood as the ability to return to the initial, i.e. pre-disruption, equilibrium; in the latter, recovery is extended to the ability to regain a new steady state, without showing negative catastrophic developments due to the crisis.

This ambiguity stems from the fact that in literature there is more than one interpretation of the term resilience in the context of the economy of regions that might appear distinct. Several authors have already made their contribution in an attempt to provide a first comprehensive

review of the available definitions (see [107] already in 2002). In economics, and particularly in regional economics, the concept began to appear in the literature around the 2000s, whereas, as anticipated, it originated much earlier in different domains, from which it "adopted" the terminology of the definitions.

In his numerous studies on the topic, Ron Martin conceptualises the definitions of regional economic resilience in a more precise way. He identifies the four distinct definitions mentioned in the literature, distinguished in:

1. Engineering Resilience;
2. Ecological Resilience;
3. Adaptive Resilience;
4. Transformational Resilience [90].

The majority of studies on regional economic resilience, mainly the less recent ones, can be traced back to the adoption only of the first two definitions stated. Therefore, an initial elaboration of the engineering and ecological notions follows, with a combination of the insights found in the literature. The following two definitions of adaptive and transformational resilience are then explored.

Engineering Resilience

Borrowing from physical sciences, **engineering resilience** can be defined as the ability of a system, which is approaching some stable equilibrium, to resume such equilibrium state after a shock or disturbance [52, 75, 90, 102, 117, 123]. This definition adheres perfectly to the Latin etymology of the term, related to the idea of bouncing back, and it has been coined "engineering" by the Canadian scientist C.S. Holling in the 70s, on the grounds that this interpretation is prevalent in many engineering sciences. The transposition of the concept to the economic world starts from the premise that there is a close affinity with the macroeconomic theories of the long-run self-adjustment and the **self-restoring equilibrium**, supporting the ability of the economy to go back to its equilibrium state after receiving an economic shock.
The focus of the engineering definition of economic resilience is on trying to maintain **stability** around a particular state of equilibrium and on the **response times of recovery** to the pre-shock steady state. Stability is the only core feature for defining the resilience of a region, due to the predictability in terms of the restoration of the path and the pre-shock conditions [48].

An economic system is considered to be more resilient than another: if it is less vulnerable to shocks, thus reacting with a less pronounced response; if it is able to retain its pre-shock structure and function and/or if it returns quickly to the equilibrium configuration. Conse-

quently, an assessment of resilience can be made on the basis of the system's **speed of return to equilibrium** [52, 102, 107].

According to this view, shocks should be **transitory** without permanent effects on the region's economic growth trend [8]. It can be argued that the engineering definition of resilience espouses the neoclassical economic theory that sees regional economies as systems whose normal conditions are associated with a steady state of growth and market equilibrium [48]. Hence, the notion of "**self-correcting market forces**" is clearly reflected in the engineering definition: any shock that shifts the economy out of its equilibrium state automatically triggers compensatory adjustments that bring it back to that equilibrium [90]. This perspective suggests that non-resilient regions are those in which markets are not allowed to operate freely or in which various frictions restrict or delay the use of adjustment mechanisms [48].

The above considerations imply that the notion of engineering resilience privileges applications to regional studies to characterise **short-term resistance** to shocks that are merely temporary and random fluctuations around a fairly stable equilibrium. Shocks of this kind allow the pre-shock conditions to be used to assess the extent of a system's rebound. The focus is, thus, on the cyclical rather than the structural elements of an economic region whose resilience is to be investigated [36, 48].

The discussed transience and temporariness of shock impacts is reminiscent of **Friedman's plucking model** theory (see [55]). This theory holds that the economy functions like a guitar string, with the level of production standing in for the string's tension and the labour supply for the actual string. Imagine that this string is fastened to the underside of an upward-sloping board that is periodically "plucked" downward by a certain type of shock at irregular intervals. The board represents a slowly rising upper limit to the economic output. The plucking model assumes that the economy always operates at its maximum potential, but that due to various shocks, the output may fall below its potential level. This is referred to as "plucking down". Once the economy has stabilised, the output can rise again above its potential level, this is known as "plucking up". According to Friedman, the economic shocks that cause plucking down are usually asymmetrical and unpredictable, such as a financial crisis or a natural disaster. Moreover, the process of plucking down is generally rapid and violent, while the process of plucking up is more gradual and can take time. Although the magnitude of the decline caused by a shock varies from one crisis to the next, it is assumed that output rebounds to the level of the ceiling board in each case. Thus, asymmetric and unpredictable shocks may cause rapid and violent changes in economic output, but such shocks will always be transitory and have no permanent effect on the economy's long-run growth trend, so they will last until the economy stabilises and starts growing again gradually.

The parallelism between the engineering notion of resilience and Friedman's plucking model is illustrated in Figure 1.1. The regional production, or employment, is represented on the vertical axis and time on the horizontal axis. The slope of the time path of output (or employment)

reflects the constant growth rate discussed. The decrease to the minimum of the function represents the impact of the shock on the output of the economic region. The region in this case is resilient according to the engineering definition since, as it recovers, regional output and employment return to their pre-shock level and resume the same pre-shock growth rate. Therefore, the assumption of the transience of impacts and the return to pre-determined equilibrium is respected.

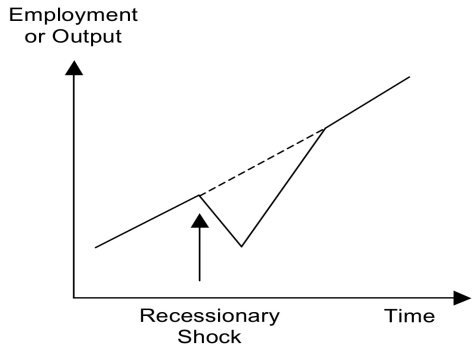

Figure 1.1: Graphical representation of resilience according to the engineering definition, from [90].

Ecological Resilience

Ecological resilience, mostly stemming from the ecology discipline, investigates the case of a system that is moved into another regime of behaviour due to a shock. This term was also coined by Holling, distinguishing it from engineering resilience and calling it "ecological" because it was considered more appropriate in the case of ecosystems adapting and recovering from perturbations.

Shifting into the realm of the economy of a region, the term resilience in this perspective is associated with the ability of a region to tolerate shocks without collapsing into a new version of itself, characterized by a different set of structures and processes [90]. However, two slightly different connotations of ecological resilience can be found in the literature.

According to one first possible connotation, ecological resilience refers to the extent to which a shock can be absorbed by a region in its local stable domain, before it is induced into some other stable equilibrium, departing from the former state [8, 75, 90, 123]. Thus, the focus is on the **scale of the shock** itself: the larger the magnitude of disturbance that can be tolerated, the higher the resilience of the region.

In other uses of the notion, the idea alludes to the system's ability to quickly transition to an improved stable equilibrium. The focus is on the **evolution** of the system, which is pushed beyond its "elasticity threshold" to a new domain [90]. Intuitively, according to this second

connotation, the measure of resilience will no longer be related to the amount of shock that can be absorbed, but rather to the characteristics of the new stable equilibrium that has been configured. A region will be considered resilient if the performances, as intended to be measured, of the post-shock domain are improved on the initial condition.

This second connotation seems to be less prone to criticism than the first. Indeed, measuring ecological resilience on the basis of the magnitude of the disturbance that can be tolerated before the system changes structure seems to evoke the engineering definition of resilience, since it is a matter of accommodating shocks by returning to the structure prior to the shock. Therefore, it is difficult to see how this view of ecological resilience gives the construct a certain evolutionary value; contrarily, if resilience is seen as a system's ability to modify its structure and behaviour in response to shocks, then much more room for evolutionary study may become available [117].

Given the previous arguments, in this perspective, economic systems are considered to be characterized by multiple stability domains [107]. This recalls the economic concept of **multiple equilibria**, which holds that an economy can be moved from one of these equilibria to another one by a shock. In other words, there is no single equilibrium state or path, but there could exist different equilibria with substantial structural differences between them. The assumption is that a resilient regional economy is one that successfully adjusts and resumes, or even enhances, its long-run equilibrium growth path. Similarly, a non-resilient economic region appears "locked in" an outdated structure and fails to change, harming its long-run development path [117].

Partially related to this idea [1], it is possible to see that the notion of ecological resilience is also related to the concept of "**hysteresis**", since disturbance affects the economic growth path permanently [90, 92, 111]. Hysteresis is the term used in economics to describe a situation in which even a short-term shock or disturbance to the economy has a sustained or long-lasting impact. This indicates that the economy is less likely to be able to return to its pre-shock level of output or employment and that the shock may have a long-lasting effect on the growth rate and potential output of the economy. For instance, [111] defines hysteresis as the case in which a "one-time disturbances permanently affect the path of the economy", giving the idea of this "memory" or "remanence" that an economic system carries along its path.

Hysteresis is highly valuable and partially complements the notion of resilience itself [90]. Resilience focuses on maintaining system functioning and performance in the face of external changes and disturbances; hysteresis concentrates on understanding how these changes and disturbances can alter the system's operation and effectiveness. These considerations suggest that it is crucial to recognize the potential for hysteresis effects when designing policy responses to short-term shocks, as they may require more extensive and sustained interventions to mitigate

[1] The notion of multi-equilibria and the one of hysteresis are said to be only partially related because the assumption of equilibrium is not essential to the notion of hysteresis, as it is in the multi-equilibria theory. Thus, even though some scholars combine the two notions, there is no need to invoke multiple equilibria in the interpretation of hysteretic path dependence [90]

their long-term (or even permanent) consequences.

Figure 1.2 shows, again in stylised form, the case of a shock creating a hysterical downward shift, i.e. "**negative hysteresis**", in the growth path of a regional economy. This means that the new normal state is less performing than the pre-shock equilibrium in the short term and that the "new normal" conditions reflect these losses.

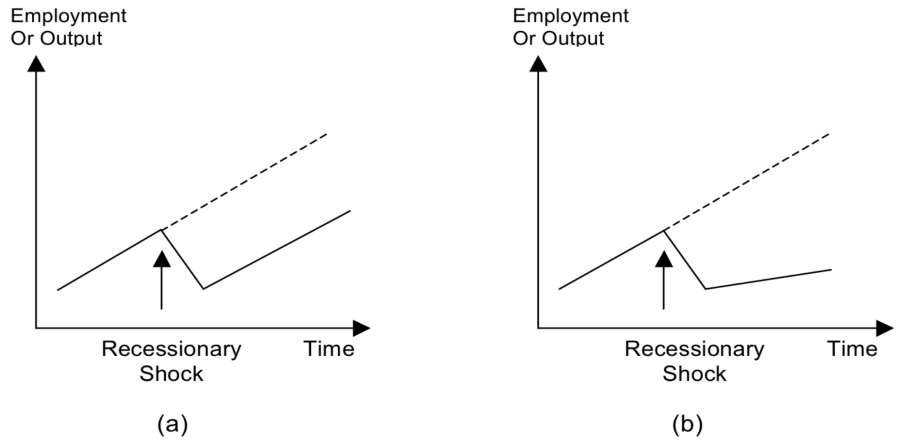

Figure 1.2: Graphical representation of negative hysteresis: (a) Permanent decline in output/employment level, recovery of pre-shock growth rate; (b) Permanent decline in output/employment level and growth rate. From [90].

In particular, two alternatives are possible in this situation:

1. In the first case, (Figure 1.2 (a)), a shock non-transitively lowers the output (or employment) level of a region, but the economy may be able to resume the pre-shock growth rate on a permanently reduced output (or employment) trend path. This implies that the slope of the line does not change, but it is shifted downwards after the crisis. This could happen considering the example of a region strongly specialized in a certain industry, hit by an economic crisis that causes the death of many firms and jobs in that industry. In this instance, the former employees of the affected industry may decide to move to other regions or convert to other sectors. Hence, even if the economy's growth rate recovers, the region may show a permanent reduction in the employment level.

2. The second case, (Figure 1.2 (b)), shows a more pathological case of negative hysteresis, in which not only is the output (or employment) level severely hit by the shock, but the economy is unable to restore the previous growth rate. Martin exemplifies this with the case of a strong de-industrialisation of a region due to a deep recession, such that the destructive aspects of the economic downturn counteract any "creative destruction" and the creation of new enterprises and jobs. Taking the same example as above, the crisis in the affected sector spreads to other sectors: the correlated effects on several sectors lead

to a permanent contraction of the entire economy of the region. Thus, both the region's output/employment level and its post-shock growth rate decrease.

In both of the exemplifications shown in Figure 1.2, the economic situation in question is deemed to be worse than before the shock, thus the ecological resilience is said to be low.

The majority of discussions on hysteresis focus on the detrimental impacts of shocks. However, there is also the possibility that positive effects can happen. Nonetheless, the inverse of what is discussed above is conceivable, resulting in a "**positive hysteresis**" process. This is the case, for example, of a disruption freesing up productive resources by driving out the least efficient businesses, if these resources are then utilised more productively within the local economy [48, 90, 91].

Figure 1.3 shows the stylized representation of the cases of positive hysteresis, in which the economy is able to recover from a recessionary shock and shift to a "superior" condition.

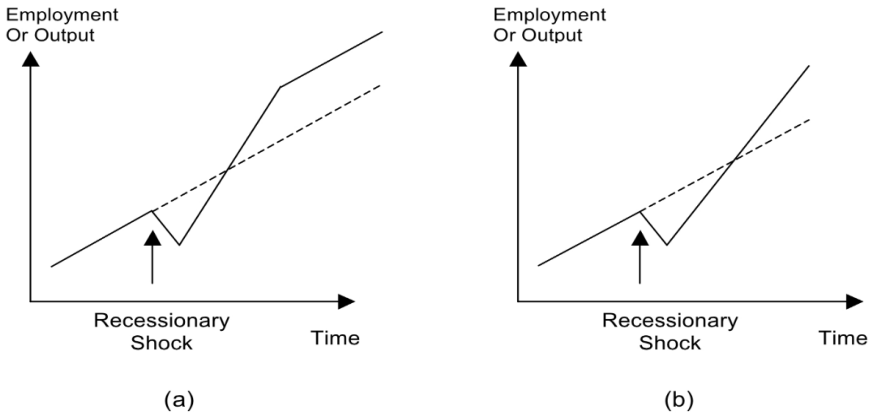

Figure 1.3: Graphical representation of positive hysteresis: (a) long-run improvement in output/employment level, recovery of the pre-shock growth rate; (b) long-run improvement in output/employment level, higher growth rate than the pre-shock rate. From [90].

In both scenarios, the region's economy more than rebounds from the recessionary dip, exhibiting a significant degree of ecological resilience to external shocks. The difference between Figure 1.3(a) and Figure 1.3(b) is that, in the former, the growth rate returns to its pre-recession level, while, in the latter, the economy of the region acquires a sustained higher pace of growth than the initial state. The question is whether this growth rate following the shock can be maintained. The economy may then return to its pre-shock growth path, though at a permanently higher level of output/employment ((Figure 1.3(a))) if the "growth ceiling" is reached, for example, because the region cannot attract the additional resources (capital and labour) required [90]. Otherwise, the shock may open up opportunities for new waves of innovation able to provide new resources and increase productivity, determining that the recovery rapid growth may be sustainable in the long run.

Comparing Engineering and Ecological Resilience

Following the preceding excursion into the definitions of resilience according to engineering and ecological perspectives, along with their respective key characteristics and references to economic theories, the following section presents a comparison of the two definitions.

Both definitions centre on the notion of **equilibrium**. On the one hand, the engineering definition considers the rebound to the initial steady state; on the other hand, the ecological definition breaks from the former definition since it does not consider the effect of the disruption as temporary, but as leading to a different equilibrium. In this regard, the engineering definition may seem more "simplistic" or even not applicable to real contexts. Actually, there would be firstly the need to contextualize what is meant by a shock (see Section 1.2.1), but even assuming the intuitive meaning of shock as an exogenous perturbation, it is far-fetched to assume that a region can return to the exact previous equilibrium. In fact, the concept of a single-equilibrium and the restoration of pre-shock conditions is often applied to one or a few variables, such as output or population, with little regard for the interplay between various aspects within a complex system such as a regional economy [100]. This in itself already implies a limitation of the model, which fails to grasp the system in its totality and integrity but only conceives of it as the sum of several factors that can be studied independently. This gap stems from the application of the plucking model to the economic resilience of a region since there is no reference to the impacts of the shock on the region's economic structure, unlike in the ecological definition.

In this way, an important component of systems is overlooked, making it difficult to reconcile the notion of resilience with the idea of **regional economic evolution** [117]. Structural changes are highly likely to occur, even in the absence of external shocks, and they may feed back to influence a region's resilience in the future [90].

The adoption of the engineering definition, therefore, translates into the necessity to pay attention to which specific component of a region's economic (or non-economic) performance is intended to be investigated and the analysis needs to be made neutral for the structural components, varying over time. Nevertheless, it is conceivable to assert that a region could regain its pre-shock growth trajectory, but only by restricting the analysis to a few key variables [90].

On the other hand, the ecological definition appears to be more complete than the engineering one, as it recognizes the presence of a "memory" of the system under analysis, which will naturally exhibit different dynamics and structures.

It should be emphasised that the above considerations (engineering as a simplistic definition vs. ecological as a complete one) apply if both definitions of resilience are applied to the same time horizon. Indeed, in the long run, it seems hazardous to assume that a region must return to pre-shock equilibrium to be considered resilient (according to the engineering notion). Instead, from a methodological viewpoint, both definitions are interesting and complementary when distinguishing between the short and the long run. In particular, the two definitions can co-

exist considering that engineering resilience is primarily to be applied to the measure of a region's immediate reaction to an exogenous shock. At the same time, the ecological perspective focuses on how the shock persistently modifies the system's behaviour in the long term and thus on the durable performance that sustains the region under observation [24, 36, 117].

Moreover, the comparison between the two definitions can be enriched if the notion of **path-dependency** is taken into account, since they interpret it very differently.
More precisely, path dependency refers to the idea that the historical background of a system or economy can shape its current and future development, creating a path that can either lead to a desirable or undesirable outcome. For example, the establishment of a new local industry, rather than being the result of chance, may be partly encouraged or enabled by the pre-existing resources, competencies, skills and experiences acquired from prior local economic growth trajectories and patterns. On the other hand, in other regions, the local environment may be less favourable, possibly even a "constraining" factor, exactly for reasons related to their prior economic history [117]. Indeed, the context in which experimentation and deliberate or intentional competition between local agents take place is shaped by these hereditary factors and the context itself can forge them in turn.

This concept is highly intuitive if applied to the context of competition between firms, hence related to the issue of competitive advantages and firm-specific competencies. Considering a firm that is able to build its competitive advantage on a product and process innovation, this would be the result of skills, know-how and economies of learning built over time, which allow the firm to realize the innovative product with reasonable costs. Even though it is possible for other firms in the industry to reverse-engineer the innovative product, it is not equally possible for them to acquire, merely by copying, the specific *dynamic capabilities* of the firm that conceived and incorporated the innovation into its business. The idea under discussion is not just applicable to the world of business, but it is extendable to any economic system reality, which consists of resources and capabilities that are acquired over time. These systems, subject to an exogenous challenge, respond differently in the short term and, similarly, they will develop long-term response methods that have inevitably been shaped by experience. This means that past events will determine certain effects, which economic activity can only partially change.

Therefore, the notion of path dependency can be construed with positive connotations, referring to historical heritage as a resource; however, also a negative interpretation may apply. This view contends that a system's future is *locked in* to a predictable trajectory, even though it may not necessarily be the optimal one, purely because of the cumulative effects of all the decisions made over a lengthy period of time.

At this point, according to the engineering definition, a regional economy is considered resilient if it can continue along its locked-in development path, despite being disrupted by an outside shock of some type. Lock-in is thus viewed as a positive feature in a regional economy. Instead, the most current and widespread viewpoint of lock-in is connected to the ecological view of

resilience and sees it as a negative trait. Indeed, resilience is intended as the avoidance of path dependency or divergence from it, as if new growth paths necessarily detach from the previous ones and as if regions must flee their historical imprints to accomplish that. This view holds that history tends to be detrimental because it necessarily links the development of regional economies to their historical trajectories, leaving little room for transformation or renewal [71].

Adaptive Resilience

The concept of **adaptive resilience** was introduced well after the initial distinction between ecological and engineering resilience and, compared to the two previous definitions, takes one step further. This perspective embodies a considerably more holistic view, transcending the simplistic, equilibrium-oriented concept of resilience, and instead, it endeavours to integrate the real and complex dynamics that characterize economic systems.

The notion of positive adaptive resilience was already widely used in the field of behavioural psychology to describe the adaptive skills that shape people's ability to maintain or quickly regain psychopathological well-being following stress, trauma or crisis of any kind [92, 94]. However, its meaning was soon expanded to many different areas and applied for the first time by Martin to the study of regional economies, referring to the ability of a regional economy to reconfigure, thus *adapt*, its structure in order to minimise the impact of a destabilising shock [90]. This perspective breaks from the equilibristic approach referred to by the engineering and ecological definitions: rather than the property of a system, resilience is configured as a **dynamic process**. In other terms, resilience is meant to be an iterative process of continuous transformation and revisions rather than the system restoration of a specific point of stability (pre-existing or new).

In this sense, the adaptive definition of resilience resembles the Shumpeterian notion of *creative destruction*, according to which innovation destroys current technologies and industries, but such destruction embodies a positive connotation by freeing the market from the obsolete. This leaves room for new opportunities for economic development, higher productivity and further innovation. Similarly, a shock, disrupting a regional economy, may create opportunities for economic growth that could not even be envisioned prior to the shock, due to the deep structural change that it determines. In this way, regions are forced to forge new growth paths to counteract the unavoidable tendencies of stagnation and decline of their local economy [112], and eventually enhance their potentialities.

Hence, regions are considered resilient if they are capable of adjusting to shifting market, technological, and industrial conditions over time; whereas regions lacking in resilience are those that can only barely or slowly adapt to unpredictable and mutating environments [48]. In a socio-economic setting, such adjustments may be consciously made by individual or collective agents to anticipate or prepare for specific shocks or, at least, to lessen their effects should they occur again in the future [92].

The definition of adaptive resilience is closely related to **Complex Systems theory**, as both areas of study focus on understanding and managing systems that are characterised by a high degree of interconnectedness, uncertainty and unpredictability. In particular, this conception of resilience may also be associated with the idea of "robustness" used in the Complex Systems theory. While the previous definitions refer to the original meaning of robustness as the ability of a system to remain untouched by shocks, this one follows the evolution of the definition toward the system's ability to withstand external and internal perturbation "by undergoing, if necessary, plastic change in some aspects of its structure and components in order to maintain or restore certain core performances or functionalities" [92].

This makes it fundamental to deeply understand and analyze how the interplay of geographical and temporal components affects the way local economies respond to negative occurrences. Hence, the temporal horizon to consider widens and the reasons behind a region's ability to immediately adapt to sudden shocks and those underlying its ability to support growth in the long term demand equal consideration [16]. All this suggests that the definition of adaptive resilience simultaneously incorporates two close but not coincident concepts: **adaptation** and **adaptability**. The former is concerned with a region's ability to grow along predetermined trajectories by using local resources to replicate already-existing models. The latter, on the other hand, refers to a region's ability to advance by fostering and building new development routes by allocating resources to purposes that differ from the current ones. [64]. Therefore, according to the adaptive resilience perspective, there is the need to analyse short-term reaction skills (adaptation), which will therefore use the same resources, and longer-term abilities (adaptability), which instead involve the creation of a new economic structure.

These considerations pave the way for an interpretation of this new definition of resilience that takes into account what was said earlier about the engineering and ecological definitions being focused on different timeframes, i.e. the former on short-term reaction and the latter on long-term reaction. In particular, since adaptive resilience asks for both perspectives at the same time, it can be argued that the need to create this new definition of resilience, after the former exclusive distinction between engineering and ecological, stems from the necessity to establish a unique meaning that can capture all the different facets of this complex notion.

In this sense, the adaptive definition may be intended to combine the engineering and ecological meanings of resilience and establish a clear connection between regional development and reaction to shocks. Resilience is here referred to as a "more general complex set of economic, social and institutional traits characterizing the ability of a regional or local economy to recover from shocks lato sensu, adapt to structural changes, move to new development paths, maintain or modify its long-term growth pattern" [35].

However, according to [96], a certain degree of overlap can be identified between the definition of adaptive resilience and ecological resilience, but not with the engineering one. Based on this view, rather than the combination of engineering and ecological definitions, adaptive resilience

is conceived as an insightful interpretation of ecological resilience identified and explored using complex systems theory and related tools.

Even though they use different tools and theories (on the one hand multi-equilibria approach, on the other hand the complex systems theory), both definitions take into account the evolutionary character of the economic resilience of a region, which itself changes over time. There is also a shared understanding that a shock leads to the configuration of a new system, which cannot be traced back to the pre-existing one. On the other hand, engineering resilience seems more related to conventional global stability theory and neglects the evolution character of the concept, therefore it may be understood as a definition in its own right.

Despite this, the usage of different tools and especially the departure from the notion of equilibrium is believed to be enough to recognize the adaptive one as a new definition, which perhaps draws on the ecological definition but does not replace it.

Overall, considering this evolutionary theory, resilience can be considered a dynamic and evolving process, defined in terms of "bouncing forward" to new growth paths rather than "bouncing back" [15, 34, 117]. Hence, it must take into account all the three following characteristics of a system:

1. the degree of change the system may experience, while still remaining in its field of attraction;
2. its potential for self-organization;
3. its ability to develop the capacity to learn and adapt [23].

According to [68], the aspect of resilience that displays the learning element of a system's behaviour in response to disruption is called *adaptive capacity*. In this regard, an interesting theory to expose for a more complete overview is the panarchy model of **Adaptive cycle principle**. It turns out to be extremely important in structuring the concept of dynamic resilience as it offers a conceptual framework that posits novel, empirically testable assumptions concerning the economic resilience of regions. In particular, according to [100], this model suggests a dynamic approach to resilience, in which resilience levels undergo continuous fluctuations as systems adapt and undergo transformations: resilience evolves throughout the course of the adaptation cycle and specific aspects of resilience become more significant at distinct stages of it [69, 117].

The adaptive cycle theory holds that complex systems, such as ecosystems, societies and economies, do not tend to attain a state of equilibrium, but, as shown in Figure 1.4, rather move through **four distinctive phases** [117]:

1. rapid growth and exploitation;
2. conservation;

3. collapse or release (creative destruction);
4. renewal or reorganization.

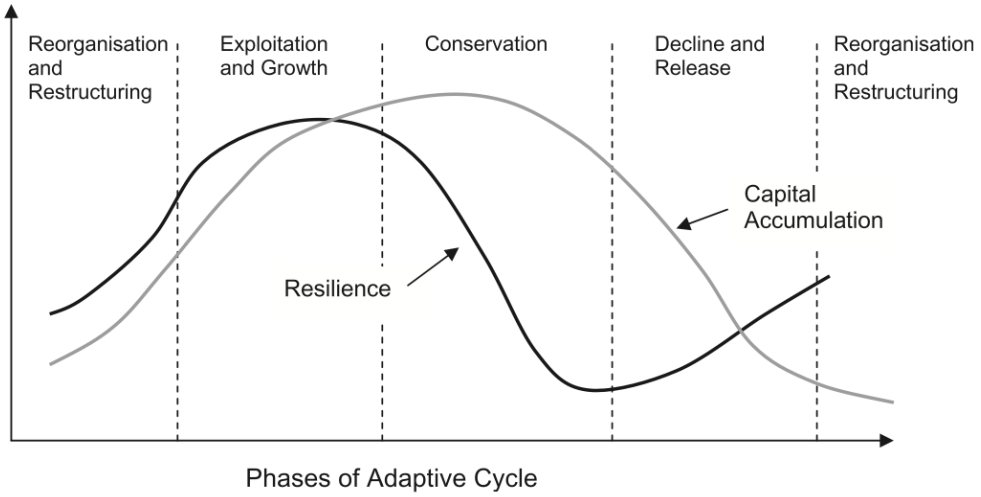

Figure 1.4: Resilience as a dynamic process. From [117].

Three components define each phase [76, 100, 101]:

- the system's estimated quantity of available resources (in the regional economic realm infrastructures, skills of local workers and firms);
- the degree to which actors or components are interconnected within the system (for example relations and dependence between firms, supply chains, firms' structure and networks);
- "resilience", considered high during phases of innovative and flexible reaction to shock (related in the regional economic realm to innovation capacity, entrepreneurial capabilities and similar.).

The four phases are organized in 2 loops:

- the first comprehends rapid growth, exploitation and conservation and pertains to the emergence, development, and establishment of a specific economic structure and trajectory of growth;
- the second includes release and renewal and refers to the eventual inflexibility and decline of that structure and trajectory but also to the rise of fresh opportunities for new activity and sources of growth that can be exploited. The most significant changes occur during this second cycle: indeed, although the system may lose some components and attributes after the shock, it is also the phase when novelty and innovation usually flourish.

As the cycle starts again the system settles into the new path and, while the possibility of any more innovation arising is shrinking, the system is capable of growing more complex as new connections are established [23].

This idea of continuous adjustment solves the trade-off between connectedness and resilience characteristic of complex adaptive systems: specifically, as a system's components become more interconnected, it also becomes more structurally and functionally inflexible, making it less adaptive overall.

In particular, applied to the regional economies, during the exploitation phase local industries benefit from comparative advantages and external economies of localization, thus the region enjoys growth and builds up productive, human, and intellectual capital. Yet, as this evolution continues, the regional economy's many components become more intertwined and its growth pattern becomes more inflexible, which lowers the region's resilience to possible shocks. In the event of a shock, structural deterioration and a lack of impetus for growth are likely to follow: businesses may shut down, relocate or leave the area, connectedness may deteriorate, and the influence of agglomeration economies may be reduced. Old institutional structures and industrial patterns fall apart as a result, releasing resources. Hence, a second release-reorganization loop took place, characterized by innovation, experimentation, and restructuring, during which new activity types started to show up. In this stage, connectedness is minimal, new growth paths are likely to be created, development paths are more open, and resilience is strong. A new cycle of regional expansion and accumulation follows the renewed utilization of new activities and technology, leading to the emergence of new comparative advantages [117].

The panarchy model of the adaptive cycle underscores another important insight for this research, namely the relationship between the **scales of analysis**. Indeed, not only do large scales influence and shape the behaviour of small scales, but the reverse is also true, particularly during the release period [117]. A current example of this mutual dependence can be identified during the COVID-19 Pandemic. For example, while decisions made at the national level influenced individual regions that had to adapt them to their own context, the presence of an outbreak within a region made the whole nation move accordingly. Therefore, it becomes important to analyze the behaviour of both large and small scales and how they influence each other, both in the short and long run.

As useful as this model comes back to better understanding regional economic resilience, it is necessary to keep in mind that its origins start from the realm of ecological systems, whose evolution can be modelled and often predicted as a result of careful analysis. In contrast, economic regions are composed of individuals and institutions that interact and can change the predetermined evolutionary path by their actions, not necessarily as a result of a shock. So, the validity of the model is to be carefully evaluated on a case-by-case basis.

Furthermore, the model allows us to identify a further underlying feature that is crucial to keep

in mind, namely the **system perspective**. Indeed, while examining the literature on resilience across several different fields, it was identified by Foster, Pendall and Cowell as a recurring theme that can be leveraged to better understand metropolitan areas' regional dynamics with the aim of using resilience as a guide for policy and planning purposes [100].

Precisely, the systems perspective involves taking into account both internal and external influences that may strengthen or weaken the system. Resilience no longer depends on a single indicator of economic performance or on a single indicator at a given time; rather, it considers interactions and interconnections between the numerous stakeholders and constituents of a system.

Transformational Resilience

According to Martin, it is possible to identify a fourth definition of resilience, namely **transformational resilience**, that involves "the redeployment of resources and the reorientation of system dynamics and performances to achieve a more sustainable and viable state of the system in question" [92].

The premise behind this is that a shock's size or type may threaten a system's very viability or sustainability, demanding not only a - either partial or selective - adaptation, as stated in the adaptive definition of resilience, but rather a complete overhaul of its structure, function and regulatory mechanisms [92]. In other words, resilience refers to the system's ability to create a **new configuration** that can successfully address the challenges and pressures it faces, ensuring its continued stability and success as "no region can rely on its legacy of past successes to succeed in the future" [119].

Upon comparing the adaptive and transformational definitions of resilience, it seems that the latter does not represent an entirely novel concept, but rather constitutes a more radical and succinct evolution of the former. However, this perspective exhibits limitations as it fails to acknowledge that in response to a shock, it is not always imperative to implement extreme and revolutionary changes to the system's structure.

In instances of sudden and severe shocks, the process of repairing extensive damage and reconstructing something that has been nearly obliterated may seem more arduous and time-consuming than initiating an entirely novel approach. Nevertheless, there are circumstances where, despite the apparent strain and time investment, the most effective solution involves restoring the conditions necessary for reconstructing the pre-shock system — a system that functioned and was selected for a specific reason. For these reasons, instead of categorizing this perspective as a distinct fourth definition, it is considered more appropriate to regard it as an extension of the adaptive definition. Such extension highlights the importance of recognizing that, if required or deemed preferable by the situation, the system may not merely undergo a superficial adaptation to the new context, but instead experience a complete transformation.

1.1.2. Comprehensive Definition of Resilience

After this overview and analysis of the already existing definitions of regional economic resilience, it is possible to draw some conclusions with the aim of arriving at a **comprehensive definition** that synergically underpins the previous ones to become as generalisable as possible. In fact, referring to different definitions means having different measurement intentions. This makes the attempt at analysis and research itself complex and the comparison of different studies even more difficult. Having clarified the purpose, it is given here an overview of the ideas that seem most relevant.

Firstly, an interrogative revolves around whether the history of the adoption of different definitions over time may indicate something important in itself. In particular, the definitions of ecological and engineering resilience have been universally recognised in the literature for a long time, ever since the concept of resilience began to be applied to economic systems. As previously said, this terminology, which originated in different fields, was then adopted for the analysis of a region's economic resilience. However, this is not the case for adaptive resilience, which seemed to emerge almost as a kind of reaction to the previous definitions. Adaptive resilience is not a transposition of concepts from different fields, but a notion born for the specific field under focus (the same applies to transformational resilience).

At this stage, the question arises as to why scholars felt the need to coin this new definition. Undoubtedly, the deepest break with the "past" definitions lies in the decision to reject the notion of equilibrium, the cornerstone of ecological and engineering notions of resilience. Indeed, adopting a region as the system under analysis, is it ever really in equilibrium?

While ecological systems may achieve equilibrium or stable states if left alone, economic systems are certainly different: regions' firms, organizations and institutions are always evolving and adjusting to their economic contexts. These transformations are increasingly being driven by the development, acquisition, and commercialization of new knowledge. Thus, according to evolutionary economists, economies can never be in equilibrium [117].

With this type of evaluation, the need to consider resilience as an **evolutionary process** rather than the recovery of an old "stability" or the attainment of a new state becomes very clear. In practical terms, the literature analysis makes it quite clear that understanding the resilience of an area following a shock does not necessarily need to be based on assumptions about equilibrium. This consideration is not intended to repudiate definitions that use the notion of equilibrium, but more trivially to suggest that equilibrium can be used (if needed) as a measuring tool to simplify analysis since it allows the modelling of the initial and final situation of a region easily. However, equilibrium is not and should not be at the heart of resilience assessment because this approach may fail to recognize resilience as much larger than analyzing a regional economy's vulnerability to shocks, and it frequently portrays the region as an autonomous spatial entity [26].

In conclusion, the different definitions of regional economic resilience have the potential to be combined to converge toward a single and shared definition. In fact, the definitions are not radically separated, but a good degree of overlapping is discernible as discussed in previous sections. Moreover, in this regard, research conducted to analyse the resilience of Spanish provinces to the Great Recession showed that when applying separately the definitions of engineering, ecological and adaptive resilience, the summary results did not change and the different definitions were correlated: the regions that perform well under the adaptive resilience notion are likewise the ones that are most likely to prove resilient under the engineering and ecological perspectives [8].

Martin made an interesting contribution, with an **integrative definition** that fits with the considerations made: regional economic resilience is defined as the capacity of a region to withstand or recover from shocks to its developmental growth path, if necessary by undergoing adaptive changes to its **economic** structures and its **social** and **institutional** arrangements, to maintain or restore its previous developmental path, or transit to a new sustainable path characterized by more productive and equitable use of its **physical**, **human** and **environmental** resources [92]. Therefore, resilience is a complex, **multidimensional** feature of regional economies.

Related to this definition, the author also proposes a useful framework to move from a conceptual definition to a more punctual perspective for measurement purposes (see Figure 1.5). According to **Martin's Framework**, regional economic resilience encompasses four separate but interrelated dimensions that give full meaning to the notion and is useful to describe the interplay between regions and shocks empirically [48, 90, 91].

1. **Resistance**, which can be defined as the vulnerability or the sensitivity of an economic region to disruptions and its capability to resist them. In this phase, the region needs to be able to avert, lessen, and survive shocks. This calls for thorough planning, efficient resource management, a solid infrastructure, and effective governmental institutions.

2. **Recovery**, which is associated with the speed and extent of the region's reaction to the shock and its ability to restore its previous performance and economic functioning. To increase recovery capacity, the region must adopt policies that promote economic recovery, job creation and infrastructure reconstruction.

3. **Re-orientation**, which concerns the structural changes activated in the region and its ability to adapt to the new economic conditions, for instance in terms of employment and vitality of the labour market, region's output and incomes. At this stage, the region must be able to promote flexibility to ensure adaptability to new needs. For example, the spread of new technologies should be promoted, with the aim of improving efficiency and productivity; also promoting the development of new economic sectors, through the encouragement of innovation and entrepreneurship, could be valuable.

4. **Renewal**, associated with the capacity to resume the pre-shock growth paths or shift to

new trajectories. The region needs to develop a broader vision for its future, adopting policies and strategies that make it sustainable and competitive in the long term. The moves at this stage are therefore more strategic and long-term ones; examples could be investing in training and education to develop a highly qualified workforce and promote creativity and innovation.

These four dimensions are linked together, in a mutually influential way, by a series of factors such as the region's prior economic growth path, innovation level, competitiveness, human capital, institutions and so on. All of which shape the region's reaction to the shock in more pragmatic terms. The last two dimensions relate to the medium- and long-term aspects of regional resilience to an unpredictable event, while the first two categories mostly focus on the short-term phases; as a consequence and due to the temporal constraints of appraising recent disruptive events like the Great Recession or the COVID-19 Pandemic, empirical research is primarily restricted to the first two phases of Resistance and Recovery [48].

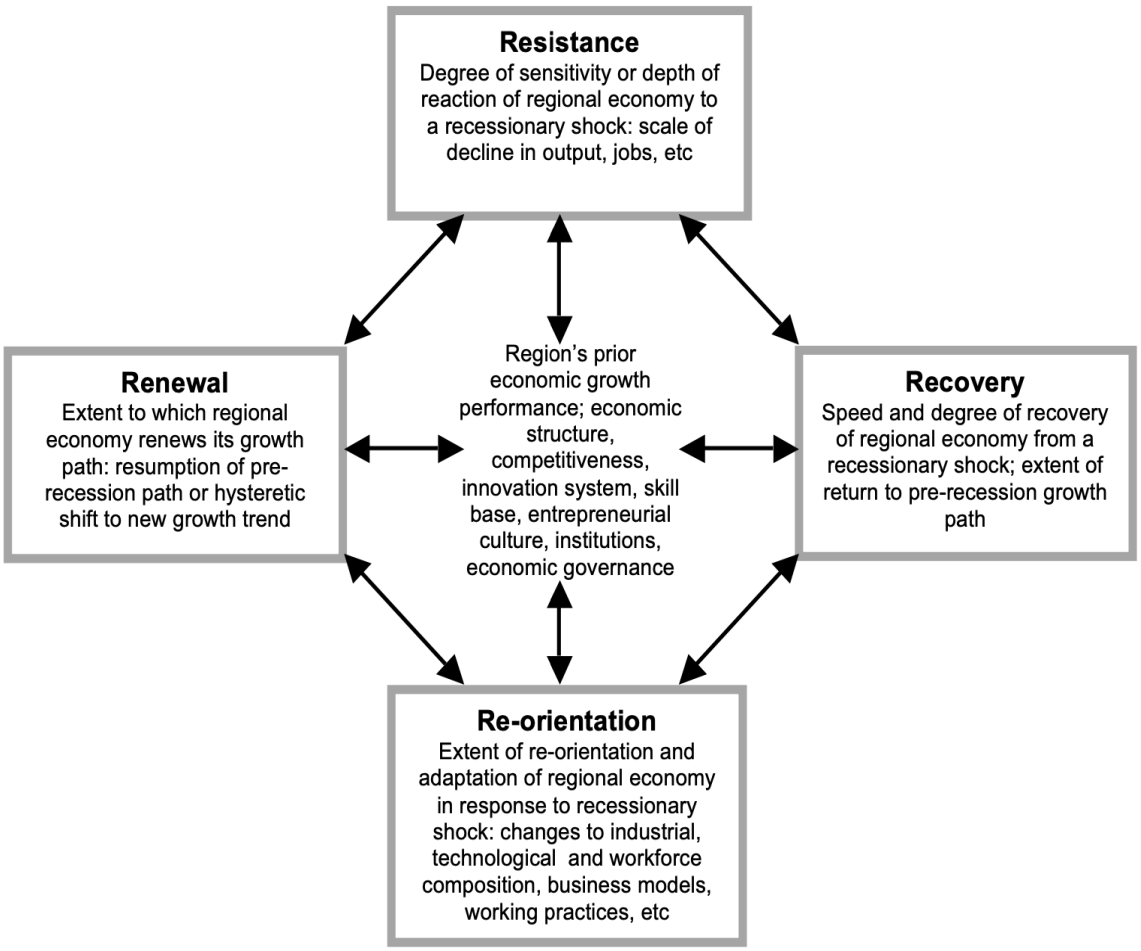

Figure 1.5: Four phases of Regional Economic Resilience. From [90].

Later in time, Martin's Framework was re-elaborated by Pontarollo and Serpieri in [103]. They used it as a reference to then create a parallelism with the **classic product life-cycle**, represented in Figure 1.6. Under this approach, resilience is interpreted as a complex process with a well-defined life cycle: resilient systems mature via stages of a growth curve, becoming increasingly locked inside a certain structure made of the Introduction stage, Growth stage, Maturity Stage and Decline/Renewal Stage.

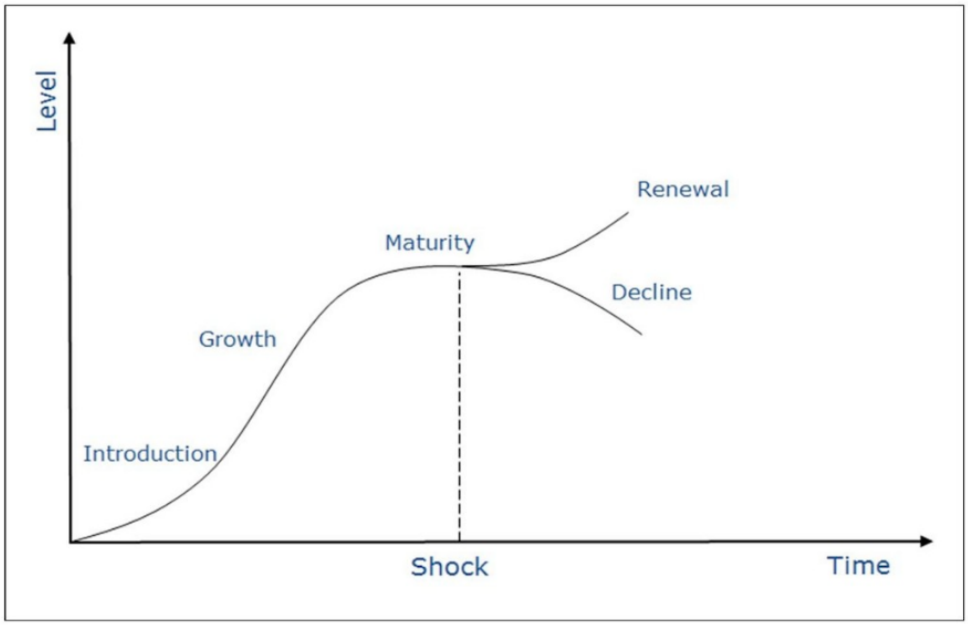

Figure 1.6: The life cycle of Resilience. From [103].

The first three phases are not independently examined since they are part of the so-called "**slow-burning process**", which gauges a region's capacity to withstand shocks over time through policy strategies. Conversely, the Decline/Renewal stage, also known as the "shock wave" or "dynamic process", is interesting as it is focused on quick exposure to an unanticipated shock over which an area has a limited amount of control. If the economy experiences a shock, two alternative dynamics may ultimately take place:

- Decline stage scenario, if the resilience capability becomes saturated or inappropriate and begins to decrease;
- Renewal stage scenario, which relates to a positive reaction of the local economy to the shock with a revitalization of its growth trajectory.

Decline, Renewal, or finally a scalloped pattern can be influenced by the ability for recovery established in the previous three stages.

Martin's comprehensive definitions and the models aforementioned remain in their intents purely **qualitative** and general. However, they represent a useful theoretical starting point to avoid constraints provided by previous definitions and a major reference framework to open up the possibility of research into a structured method of measuring regional economic resilience.

Section 1.2 advances towards a quantitative analytical perspective, delving into the crucial elements that must be defined prior to the implementation of a measurement methodology.

1.2. Toward a Quantitative Measure

The process of moving from conceptual frameworks to an agreed-upon methodology for measuring resilience is crucial but also challenging. Understanding the factors that contribute to resilience is essential to creating effective management strategies that will reduce the effects of upcoming shocks. To effectively implement the concept into regional policy agendas and practices, not only a comprehensive definition is needed, but also a clear conceptualization and understanding of what it is, by identifying the **dimensions of the analysis** of regional economic resilience. This necessitates accurate evaluations that consider not just the existing state of affairs but also drawbacks and barriers to progress [31].

Nevertheless, there are two primary issues. First of all, since resilience comprehends numerous elements—institutional, economic, social and ecological—challenges arise in the convergence of all the dimensions in a unique measurement and in considering how different changes interact and overlap with each other. Secondly, as already mentioned, resilience-defining factors are dynamic and eventually vary across different spatial, social and temporal scales. As a result, it is essential to define whose state of the system is being examined and which perturbations are of relevance [23].

Hence, the following paragraph will be articulated in sub-paragraphs defining:

1. **Resilience *to what*** kind of shock. Resilience is associated with overcoming some sort of shock, but what precisely is a shock? How violent and abrupt of a disturbance must it be to qualify as a shock? Is there a threshold to identify? What about the pressures brought on by constant challenging forces?

2. **Resilience *of what*** geographical area. What is the level of granularity of the measure? Which territorial unit of analysis is most appropriate to construct an analysis free of bias and capable of collecting a certain degree of variety? What is the geographical area of extension of the analysis?

3. **Resilience *over what period***. Studies adopt different temporal frameworks. How wide is the appropriate time horizon of analysis to assess the resilience of a region? Which time bucket to choose? Which trends are important to capture?

1.2.1. Resilience "to what"

Several scholars outlined the importance of defining what constitutes a shock in terms of its nature in order to categorise different kinds of shocks. The first step is certainly to define the degree of the shock itself: the aim is to precisely establish a "**threshold**" for what qualifies as a shock, such as a minimum amount of loss to variables of interest or a minimum period of time with negative growth [49].

Shocks can be local, national, or even global in their genesis and typically have unequal and very destabilizing effects. Examples could be recessions, localized financial crises, collapses of a local major employer, natural disasters, global warming, pandemics, radical political transformation, terrorist attacks and so forth. Although it is sometimes argued that some of them were too foreseeable in hindsight, like the Great Recession, shocks are typically abrupt **unpredictable events** [92]. So, the inability to predict it and the sudden appearance are the initial characteristics that define a shock.

Nevertheless, some scholars tend to broaden the definition of resilience to "less acute" shocks to include how economic areas manage "**slow-burning**" pressures or "slow-moving challenges" [100], that emerge gradually and incrementally over an extended period of time. Resilience in this case would appear to be the capacity to continuously respond to such ongoing challenges, e.g. de-industrialisation, technological innovation and climate change, whose effects tend to be chronic [48]. With a critical attitude, it can be noted, though, that this process goes hand in hand with the continuous evolution of economies and markets subjected to forces such as innovation, technological progress, competitive selection, globalization and others, that challenge firms, making some of their skills obsolete and requiring the development of new ones. In simpler terms, the situation being discussed relates to the ongoing process of economic growth and development. This process can result, for instance, in the death of a firm, which may be replaced by another, making the impact on the local economy not even measurable. Therefore, this scenario embodies a completely different case than discrete sudden disruptions, whose effects on the local economy would be far from negligible. Obviously, the reaction to "proper" shocks will be largely influenced by the intrinsic and path-dependent skills and characteristics underlying the constant development process.

In addition, it is important to emphasise that some economic changes may be "slow-burn" in character, rising slowly over time, but only becoming disruptive shocks when they reach a certain *tipping point*[2] [92]. Hence, there is a need to distinguish the two cases mentioned in an attempt to provide a comprehensive definition of shocks: the first dimension of analysis will be the **threshold** in terms of the **unpredictability of arrival** and **duration** of effects, namely if the shocks are sudden and discrete events or challenges that evolve gradually.

[2]Tipping point here is intended to mean critical threshold, i.e. once the tipping point has been exceeded, the effects brought about by slow-burn pressure become such that the initial pressure becomes comparable to a sudden shock

The next dimension of analysis to consider is the **scale of the impacts**, in a nutshell, whether the shocks are local or global in scale. This dimension is more delicate since the scale of impacts can be very dynamic: it is easy for a local shock to spread to other areas, even becoming a global shock, as in the case of wars or economic recessions. These cases can be referred to with the term "***glocalisation***", meaning a phenomenon with local origins but global effects [48]. One example is the **Great Recession**, which can be said, without aiming to be exhaustive, that began as a financial crisis in the United States, mainly caused by the over-indebtedness of financial institutions and the spread of complex and risky financial instruments such as subprime mortgages. However, because of the interconnectedness of banking systems, it soon spread globally.

Or again, the **COVID-19 pandemic** had different timing of spread geographically. From local epidemiological initially spread in China, it did not remain confined for long. In fact, the virus was first identified around the end of 2019 in the city of Wuhan, but by March 2020, the Pandemic had already spread to many states, with no continent left out. This being the case, then, the classification of the scale of impacts does not refer to the origin of the shock, but to the extent of its cumulative impacts over time.

Certainly, some shocks are automatically global in nature, the glaring example is **climate change**: the effects are not entirely geographically neutral or may be difficult to measure, but they affect the globe as a whole. Therefore, "**local shocks**" are defined as shocks whose effects have remained local in time, and "**global shocks**" are defined as shocks whose effects (from the outset or over time) are spread globally or almost globally.

Some examples of local shocks may be circumscribed natural disasters, such as earthquakes for which the impacts tend to be relative to the areas adjoining the crater area, or other natural disasters such as volcanic eruptions, floods, tidal waves that affect a particular area, which may also be large but remain localised in time. Economic crises can also sometimes remain confined to a single state or even at lower territorial units. Also, the sudden bankruptcy of a large company can lead to a major change in terms of market concentration and level of competition in a region, as well as in the vitality of the labour market and so on.

It is, therefore, possible at this point to categorize the kind of shocks combining the two dimensions of analysis discussed (see Figure 1.7), namely the threshold of effects in terms of onset and duration, and the location/scale of effects.

Transversal to the dimensions of analysis described above, a third dimension useful in defining the type of shock is undoubtedly the **nature** of the shock itself, understood as the field to which it belongs, i.e. the scope of its effects. Indeed, in attempting to construct a quantitative system for measuring the economic resilience of a region, it is not enough to understand the intensity and spread of the impacts of a shock, but also the scope of the shock's effects provides valuable information on what will later prove to be the measurement drivers.

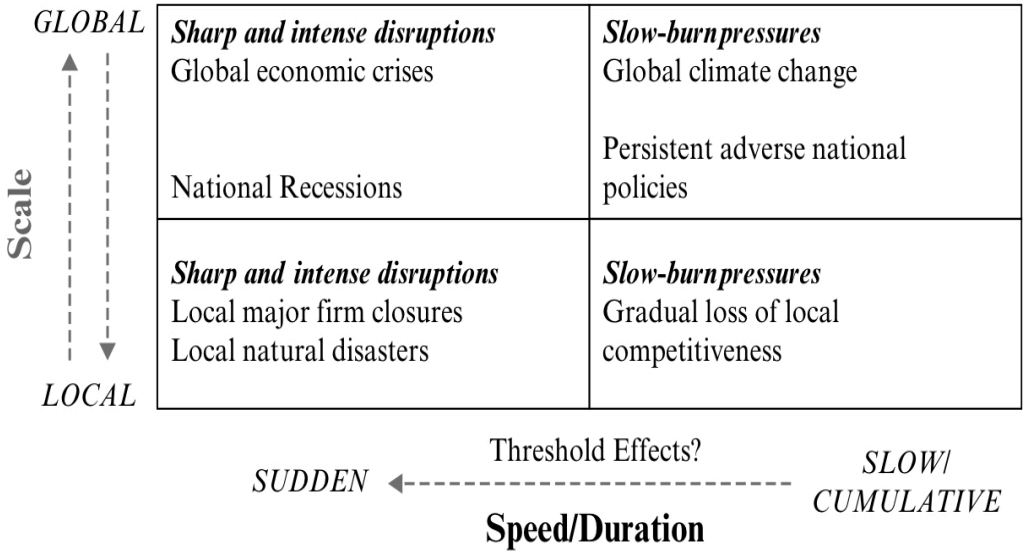

Figure 1.7: Categorisation of shocks on the basis of two dimensions. From [92].

In the section on shocks characterized by discrete and unpredictable nature, it has been chosen to place the shocks into two broad categories:

1. **Economic shocks**;
2. **External disasters**.

A necessary premise here is that the different typologies of shocks are not mutually exclusive and a regional economy may experience more shocks at the same time. In particular, although external disasters are distinct from economic recessions, it could happen, and often is the norm, that shocks of a different nature have consequences that permeate economic spheres and thus turn into economic crises for the affected areas. Emblematic in this sense is the case of the COVID-19 pandemic, which combined a health crisis with a deep economic recession in different countries in Europe.

For what concerns **disasters**, a clear definition of this type of disruption is given by the International Strategy for Disaster Reduction [3] as follows: "serious disruption affecting a community or population, causing deaths, injuries, or damage to property, livelihoods, or the environment, that exceeds the ability of the affected community to cope using its own resources".

Similarly, the Centre for Research on the Epidemiology of Disasters (CRED) defines a natural disaster as "an unforeseen and sudden event that influences local capacity causing high damage,

[3]The International Strategy for Disaster Reduction (ISDR) is a global framework established within the United Nations for the promotion of action to reduce social vulnerability and risks of natural hazards and related technological and environmental disasters. [7]

destruction and human suffering and requires assistance from national or international levels". Natural catastrophes include earthquakes, tsunamis, floods, windstorms, starvation, droughts, and epidemics; instances of technological or man-made disasters include industrial accidents, chemical spills, fires, and similar [14].

Hence, disasters are considered exogenous and periodically recurring adverse events that lead to some distortion in the areas affected. They tend to affect the region as a whole: the infrastructure, which can be damaged in a more or less radical way; the inhabitants, affecting people's lives, health and social dynamics; and the region's performance, not only in economic terms.

Extreme natural disasters' destructive impacts cannot entirely be avoided because it is difficult to prevent them from happening in the first place. On the other hand, it is possible to be ready for them by making an effort to at least partially prevent or limit their impacts, which would allow for a speedy and effective recovery of the entire system [84].

With regard to **economic shocks**, Hill's definition appears very precise. First of all, it is possible to distinguish two subcategories:

1. **national economic downturn shocks**, which encompasses the national economy as a whole. It is defined to occur when, compared to a base year, the national growth rate falls by more than 2.0 percentage points from its yearly growth rate over the prior eight years [73];

2. **industry shocks**, related to declines in specific industries that make up a significant part of the region's export base [4]. In this case, when the employment decrease in export industries reflects a one-year annual decline of more than 0.75 per cent of total employment in a metropolitan area, the region is said to have undergone an industry shock.

1.2.2. Resilience "of what"

In a general context, for the purpose of conducting an analysis as precisely as possible and acquiring pertinent findings, it is crucial to carefully select the **geographic boundaries** to be considered. In the particular case of resilience, given the multidimensionality that its definition encompasses, it becomes critically important to choose not only the area to which extend the research, namely the geographical extension of the research, but also the level of **granularity** to analyze within the selected geographic area.

The decision regarding the level of granularity changes according to the objective of the research and allows the identification of very different relationships within the area. In fact, by choosing a higher level of granularity, it is possible to go deeper into the analysis and discover more

[4]For a given year a three-digit NAICS industry is defined as a major export industry in a region if its share of regional employment is at least 1.0 per cent and is at least 80 per cent above the same industry's share of national employment.

characteristic and area-specific aspects. At the same time, however, it becomes difficult to find general patterns within the area of analysis, necessary for the identification of conclusions generalizable to areas other than those considered.

Regarding the selection of the geographical area's extension, it mainly depends on whether one wants to investigate and deepen the concept of resilience or is just interested in understanding the reaction of a specific area to a particular event. Indeed, if the aim is to discover the underlying determinants of resilience to create a model that can be applied as broadly as possible, it is necessary to collect several samples and compare diverse results with each other. Consequently, the area to be considered will be as large as possible, with the limitation being to remain in an area that has within it conditions that can be easily identified and correlated. On the other hand, in the case of a natural disaster limited to a certain area or in the eventuality of a large local company's bankruptcy, an attempt needs to be made to confine the analysis to only the area actually and directly affected and impacted by the shock.

With regard to granularity, an initial distinction regards the choice of administrative or functional areas. **Administrative units** are identified based on political or governmental boundaries, more precisely they are defined by the European Union as "geographical areas for which an administrative authority is empowered to take administrative or strategic decisions, in accordance with the judicial and institutional framework of the Member State concerned" [4].

Alternatively, **functional units** are distinguished on the basis of economic and social indicators, such as industries, social activities and economic characteristics. This segmentation enables the selection of areas with a more coherent structure and with a higher probability of following similar dynamics.
Functional areas are typically defined based on a set of criteria, including economic and social indicators, physical and environmental features, and infrastructure networks such as transportation, communication, and utilities.

Ideally, since the assessment of regional resilience characteristics usually deploys macroeconomic variables that are connected to a region's performance, such as production and employment rates of change [114] , it is important that the chosen unit of analysis represents a fairly homogeneous labour market. For this reason, in literature it is possible to identify different researches using local labour systems (LLS) [10, 49] or travel-to-work areas (TTWA) [30, 115], both obtained employing the daily commuter travel patterns based on the workers' places of residence and employment, recorded from the ISTAT censuses. In addition, a repeatedly used unit of analysis can be identified in Metropolitan Statistica Areas [73]. The Office of Management and Budget (OMB) uses the term Metropolitan Statistical Area (MSA) to refer to a multi-county cluster with a population density of at least 50,000, namely a metropolis with closely knit neighbourhoods that has a high level of social and economic integration. Nevertheless, all the previously mentioned units are often discarded as it is more challenging to locate data at this level of analysis, and doing so frequently necessitates a complex (and time-consuming) data-cleaning

procedure, particularly when a cross-temporal comparison is required [49].

Consequently, administrative units are the most used. In particular, an available system in Europe is the **Nomenclature of Territorial Units for Statistics** (NUTS), which is a system established by the European Union (EU). NUTS serves as a standardized territorial subdivision framework used for statistical and administrative purposes within the European Union, ensuring consistency in data collection and analysis at the regional level. It defines various territorial units across Europe and provides a common basis for producing comparable statistical data among different regions within the EU. The NUTS classification system recognizes three levels of regional divisions: each state member (NUTS 0) is divided into a NUTS1 region (corresponding to Italy's 11 groups of regions), which in turn are then divided into a number of NUTS 2 regions (corresponding to Italy's 20 administrative regions), further split into NUTS3 regions (provinces).

Specifically, the great majority of resilience studies (e.g., [59, 60, 110]) are conducted at the NUT2 level. Thus, selecting this unit of analysis enables a large variety of data to be accessible for comparisons both geographically and chronologically. Additionally, NUTS2 regions are the fundamental unit for implementing cohesion initiatives in the EU [47], they represent the scale at which information on innovation performance is published [6], and, generally speaking, the availability and accuracy of data are higher compared to other levels of granularity [18].

However, there is a certain amount of variability that is not captured by only looking at regional findings, as demonstrated by the application carried out by Faggian, Gemmiti, Jaquet, and Santini on the Italian regions, suggesting the need for investigating at a finer level (for instance looking at municipalities) [49].

Further support for this finding resides in Cellini and Torrisi's investigation of Italy's 20 regions (NUTS1 level), which revealed, rather surprisingly, that the regions display a high degree of uniformity in recovery aftershocks [24]. Indeed, given the contrast with later and earlier comparable research, the territorial unit of analysis utilized can be partially blamed for the outcome [49]. These applications highlight the need for greater granularity, which translated in the instance of Italy into carrying out the study at the level of provinces, namely NUTS3 level, or even municipalities, as done by [8, 54, 95, 114].

A particular unit of analysis worthy of consideration is the one adopted by Sherrieb in [116]: the **county** was chosen as the unit of measurement to represent a "community". What is interesting here is the idea of defining the unit to be studied starting from the consideration of the social aspect that characterizes the area under analysis. This dimension is very difficult to measure and is therefore mostly overlooked, when in fact it is a key feature in understanding the potential response of an area to a shock.

When studying natural disasters, since the effects and opportunities for improvement are localized and event-specific, the unit of analysis varies depending on the extent of the impact of the

disaster itself and may deviate from the common, previously defined, units of analysis. In the case of an earthquake, for example, it is usually used the crater area, defined as the portion of the earth that has been directly affected by the fraying and deformation brought on by an earthquake. In these cases, global processes are not downscaled on the local level to assess their consequences as in the global change literature. Instead, there is an ongoing search for cross-national and worldwide comparisons between similar shock's consequences as they are typically possible and lead to the aggregation of local information to broader spatial units [31].

1.2.3. Resilience "over what period"

The third and final element that is crucial to define in order to move towards a quantitative measurement of the economic resilience of a region is the **temporal framework**, which is the time horizon that is considered for the analysis. Although at first glance this might seem a more trivial choice than the previous one of defining the territorial unit of analysis, defining the "when" is not simple, since different time horizons could imply diverse results even in analysing the same phenomenon.

Firstly, there is the need to define the purpose: is the intent to investigate a region's immediate capacity to respond to disruption? Or to measure long-term resilience? In fact, it is not certain that a region that has been quicker to "absorb" immediate change is also the one that, according to a longer-time perspective, shows better performance in the future.

As already mentioned, for reasons of data availability, research may focus exclusively on the short-term, but the importance of adopting a long-term perspective is a recurring theme in the literature. Long-term perspective entails not only a focus on the previous and current state of a system but also the consideration of its evolution over time. It involves a broader outlook that takes into account how the system has developed and changed in the past, as well as how it is likely to adapt and transform in the future. This goes hand in hand with the comprehensive definition of regional economic resilience (see Section 1.1.2) that goes beyond considering resilience as the ability to withstand challenges and changes since it concerns also the ability to thrive over an extended period of time.

In addition, the choice depends on the type of shock: the definition of the "when" is inextricably linked to the definition of the "what". As a matter of fact, the analysis must inevitably include two time periods in order to be comprehensive. Indeed, the **pre-shock period** is necessary to neutralise the post-shock performance with respect to different starting conditions; the **post-shock period** enables the *a posteriori* evaluation of previous assets and resources to understand how these have influenced resilience, with respect to shock, in the future.

The pre-shock and the post-shock periods do not have a duration that can be defined *a priori* but rather depend on the type of shock. If, for instance, the intent is to focus on a long-lasting shock, like an economic recession, it could be important to use a broad time horizon to capture

long-term trends. In fact, there could be subsequent waves of recessionary shocks, as happened in Italy where, after the recession in 2009-2010, there was a short period of recovery in 2011, followed by a new recession. In this case, an analysis that stops temporally to 2011 would not be able to discover whether, for example, the 2011 rebound is correlated to longer-term growth; therefore a broader time horizon would be needed. In similar cases, the long-term costs of a shock could be far more significant than the short-run ones: it is not only a matter of immediate effects on unemployment, GDP, and social unrest but also a significant economic restructuring [21], which, of course, takes time.

Finally, in the field of regional economic resilience, the aim is usually that of identifying geographical unevenness between regions. Thus, the temporal framework needs to capture when the economic activity of each region spikes, when a downturn starts, when the accompanying trough occurs and when each region recovers, even when the analysis has a short-term scope. This is essential since not all areas experienced the crisis in the same year or recovered at the same time and this may provide analytical difficulties if standard dates for the crises' beginning are used.

Moreover, it is also relevant to keep in mind that it is not enough to look at the type of shock and the intentions of analysis, but also the territorial unit of analysis could be linked to the choice of the temporal framework. For example, supposing to use LLS, these territorial units of analysis are dynamic over time, therefore they would need some "adjustments" to be used for longer time series and it is not trivial to maintain consistency over time [49].

Once defined how long the analysis extends, another key aspect needs to be chosen: the **time bucket**. Namely, the researchers need to adopt a predefined time interval, used to aggregate data into a common time unit. Here again, there is no right or wrong choice, but it depends on the intentions of the analysis. Measuring the immediate response, which covers a narrow time horizon, might require a relatively small time bucket, as in the order of months or even days. For example, if one imagines the case of an earthquake, it might be relevant to measure the speed of rescue of people in danger and care of the injured, so data should be collected day by day or even hour by hour. On the other hand, when dealing with crises that are more spread out over time, adopting a too narrow time bucket could be too time-consuming and costly, but also probably useless. Changes in a region's economy over the long term do not occur discretely but are the result of evolutions and processes of change, and the choice of time bucket must be consistent with this consideration. Explaining these concepts is facilitated by considering examples. Considering the objective to analyse the resilience of certain regions in response to an economic crisis, one could opt for data on annual output levels (wider time bucket) or quarterly (narrower time bucket). Both have advantages and disadvantages. For instance, cyclical components (and even more the seasonal ones) of the economic growth path are a less serious problem in annual data compared to quarterly data, but, on the other hand, it may require caution and inspection on structural stability [24]. In addition, quarterly data

makes it possible to take into account potential relationships between output and employment in a specific region, demonstrating that adopting diverse time buckets allows different aspects to be captured. This results from the assumption that these factors are not fully contemporaneous at a quarterly frequency, since it takes time for employment to adjust to changes in the region's output [36].

In any case, one of the main reasons that determine the choice of a time bucket over another one is not seldom related to the **availability of data** on the chosen resilience drivers.

In conclusion, it is believed that in order to measure regional economic resilience, it is first necessary to define the 3 discussed dimensions of analysis synthesised in Figure 1.8. Once these dimensions have been clarified, it is possible to proceed with the choice of resilience drivers, which will vary according to the dimensions in the scope of the research.

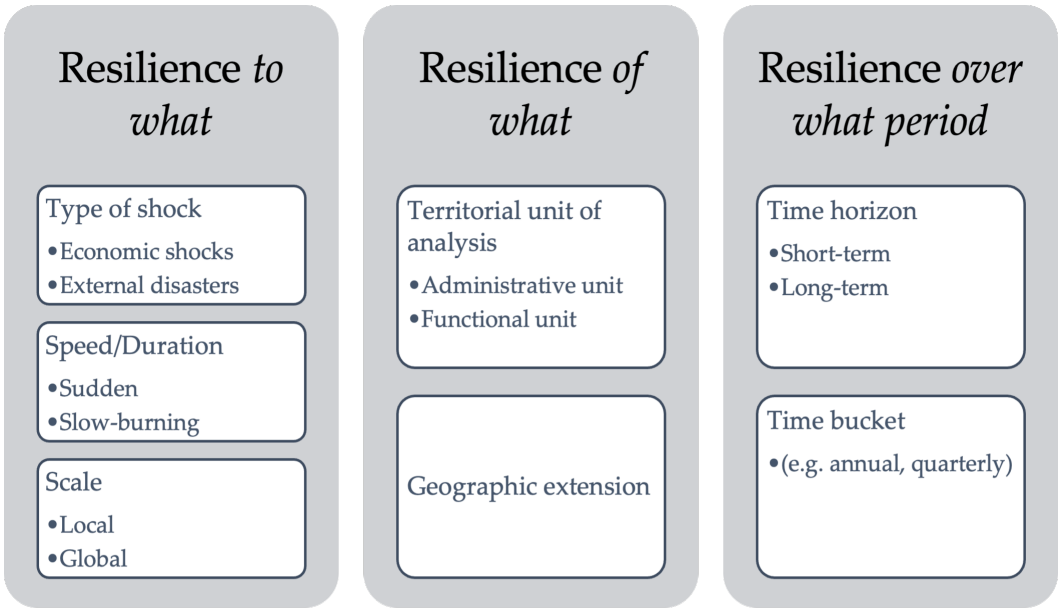

Figure 1.8: Dimensions to define to measure regional economic resilience.

1.3. Research Objectives

The final objective of this dissertation is to study the determinants of short-term resilience, answering the following research questions:

- **RQ1**: Which specific factors have played a pivotal role in shaping the diverse responses to the COVID-19 crisis across distinct provinces in Italy?
- **RQ2**: Given these factors, what actionable insights can be derived to guide effective policy-making and strategic planning aimed at enhancing short-term resilience in this context?

In order to address these inquiries, it is first necessary to clarify the research's scope and depth of analysis, guided by the possibilities explored within the existing literature. Given the number of different facets and nuances that the concept of resilience brings with it, it is necessary to focus on a specific idea, delineating the three distinct dimensions of analysis previously discussed: resilience *to what* kind of shock, resilience *of what* geographical area and resilience *over what period*.

Focusing on the typology of shock, this study concentrates on the examination of responses to **sudden shocks**, rather than extending to the gradual, incremental processes of change and adaptation typically observed in a steadily evolving and progressing economy. Specifically, given its significance, the research will centre on resilience to **COVID-19 pandemic**.

The emergence of COVID-19 in late 2019, followed by its swift global spread in early 2020, caused a tragic loss of a large number of human lives and an even larger number of severely sick people, which has triggered an unprecedented crisis in both public health systems and regional economies. In fact, as of February 1, 2021, almost a year after the World Health Organization officially declared it a pandemic, the worldwide death toll stood at 2.2 million confirmed cases, with over 102 million infections documented globally [98]. This massive global upheaval has prompted comprehensive public interventions aimed at curbing the virus's transmission, as governments universally prioritized containing the disease and minimizing mortality rates. Nevertheless, while these containment strategies are essential for mitigating the immediate health impact, they have simultaneously triggered a **severe economic crisis** whose full consequences are yet to materialize. Indeed, the stringent lockdown measures implemented throughout various countries in 2020 and early 2021 have brought economic activities to a standstill. This set the stage for an impending **employment crisis**, likely to endure beyond the pandemic's resolution, disproportionately affecting vulnerable groups like young people and women. Additionally, the Pandemic has underscored preexisting weaknesses within many OECD economies, partly stemming from the aftermath of the 2008 financial crisis [48]. These preexisting challenges risk being exacerbated by the economic downturn resulting from the COVID-19 pandemic, which could

have far-reaching implications for regional economies already grappling with a sluggish recovery from the previous recession.

Against this evolving backdrop, it is important to recognize that the character of the current economic shock diverges significantly from the 2008 financial crisis, giving rise to distinct facets of the ongoing turbulence. At the Pandemic's outset, financial markets were in a healthier state compared to 2007, allowing governments to spend more substantial resources and giving them a greater inclination to invest in stabilization and recovery initiatives. Furthermore, the lessons drawn from the aftermath of the 2008 crisis have encouraged a broader role for state intervention and expansionary policies, aimed at safeguarding businesses, preserving employment, and bolstering overall well-being [89].

Consequently, in the midst of these transformations in economic and social dynamics, emerging initiatives like NextGenerationEU suggest that the crisis also presents unprecedented opportunities for innovative policy actions and public investments [48]. Thus, the current crisis marks a significant departure from conventional approaches, offering unique insights into diverse regional responses. This, combined with the unparalleled extent of its impact on economic activities, renders the pandemic an ideal case to scrutinize regional economic resilience and collect valuable insights for addressing future shocks and building more robust economic systems.

Moving to the resilience *of what* dimension, despite the global repercussions of the COVID-19 pandemic, the study will deliberately confine its examination to the **Italian territory**. This approach avoids overgeneralization, allowing for a more focused understanding of territory-specific dynamics. For the same reason, the analysis operates at a provincial (**NUTS3**) level rather than a regional one, as the latter encompasses too many divergent variables. Indeed, NUTS3 units strike a balance between granularity and manageability, ensuring that the analysis captures relevant variations while avoiding an overwhelming number of different factors. The selection of **administrative units** over functional units, local labour systems (LLS), or travel-to-work areas (TTWA) as the geographical framework for analysis in this research thesis, is driven by the need for consistent and accessible data, by the relevance to policy and decision-making, and by the manageability of results. In fact, administrative units provide well-defined boundaries with uniform data, facilitating comprehensive analysis and ensuring findings are applicable to policy recommendations. While functional units might offer localized insights, administrative units encompass relatively homogeneous characteristics for coherent analysis, albeit avoiding data complexity and challenges in generalization and comparisons. Moreover, administrative units align with people's understanding of regions, thus enhancing the interpretability of research outcomes.

Finally, the *over what period* dimension is delineated by the choice of an **annual time bucket** and a time horizon spanning from **2018** to **2022** is dictated by data availability and the contemporaneity of the shock. This chosen timeframe serves a dual purpose: firstly, to garner insights not restricted to the immediate post-shock period but also encompassing pre-shock dynamics,

essential for meaningful comparisons. The inclusion of the years 2019 and 2018 allows for an understanding of the economic conditions and trends leading up to the COVID-19 shock, providing a baseline against which the shock's impact can be evaluated. Secondly, extending analysis until 2022 is motivated by data availability limitations, as reliable data beyond that point is not accessible. This window encapsulates the Pandemic's pivotal period in Italy, encompassing infection peaks, diverse containment measures and early recovery efforts. This facilitates observation of the shock's progression and potentially lasting effects, providing a comprehensive perspective on the examined regions' resilience in the short run.

Answering the research questions requires a **quantitative methodology**, which bridges the existing literature gap by reaching a comprehensive understanding of the short-term determinants of regional resilience that encompasses the full spectrum of social, economic and environmental dimensions. This approach allows to grasp the multidimensional nature of resilience. Particularly notable is the literature's inadequacy in assessing the environmental dimension, especially in the context of non-natural shocks, and in assessing the pivotal role played by institutions. This study strives to include these crucial aspects, giving them the consideration they necessitate.

To achieve this, a **regression model** will be developed to capture the influence of the selected determinants on the Italian response to COVID-19, modelled through **synthetic measures** grasping the fluctuations of the labour market.

In light of these findings, it is possible to draw some observations regarding the allocation of resources provided through the PNRR, namely the National Recovery and Resilience Plan, deeply investigating Italy's overall performance and preparedness for potential adversities.

This approach seeks to produce results that, while tailored to a specific instance of short-term resilience, are at the same time comprehensive and accurate in their understanding, thus allowing, in the future, for the potential expansion of the results to other areas and time-span with appropriate modifications and considerations.

1.4. Dissertation Structure

This dissertation is organized to thoroughly investigate regional economic resilience in a clear and systematic manner. The structure is designed to address the research objectives and provide a detailed analysis of the topic.

The **introduction** provides the contextual background, emphasising the relevance of regional economic resilience in today's world and in the face of contemporary challenges. It underscores the profound impact of COVID-19 on this subject and emphasizes the importance of examining short-term responses to enable actionable measures.

Chapter 1: Theoretical Background unveils the foundational framework for understanding the subject matter. This chapter rigorously defines the notion of regional economic resilience:

diving into an overview of existing literature definitions, it systematically builds a comprehensive definition, exploring its nuances and implications. The chapter also navigates through the intricate landscape of a quantitative measure, dissecting key questions such as the dimensions and periods pertinent to resilience. The chapter culminates in a clear delineation of the research objectives and outlines the structure of the dissertation.

Chapter 2: Literature Review guides readers into a thorough exploration of existing knowledge. It investigates the methodologies employed in the field, followed by a thorough examination of various measures and dimensions of resilience. Each dimension is studied by looking at the macro-areas and their constituent areas, with the intention of creating a strong groundwork to pave the way for new insights. The schematic organization of literature contributions serves as a solid foundation for determining which indicators are most suitable for the context of COVID-19 and a short-term perspective.

Chapter 3: Research Design & Model Development peels back the layers of research approach and model decisions, outlining the methodological considerations that unveiled the rationale behind the research flow and the model specifications and relative results. In other terms, this chapter serves as the bedrock of the research, setting the stage for the exploration of short-term resilience drivers in response to the Pandemic.

Chapter 4: Data Collection plays a pivotal role in shaping the foundation of this research and assuring the credibility and integrity of the findings. Within this chapter, data instruments and sources are introduced, and the intricacies of data acquisition, preparation, and validation are examined. A comprehensive overview of data refinement procedures is provided, emphasizing the critical phases of data preprocessing and cleaning. These steps ensure that the data assumes a suitable format for subsequent investigations, solidifying the robustness of the research foundation.

Chapter 5: Model validation marks a significant turning point in the dissertation. This chapter delves into the specifics of developing a comprehensive model for identifying significant COVID-19 short-term resilience drivers, starting from the definition of the model's parameters, variables, and the theoretical underpinnings that shape its formulation. Following this, the variables that wield significant influence over the short-term resilience drivers sought to be uncovered are identified. This process entails a scrutiny of the data, pinpointing the elements that play a pivotal role in shaping the model's outcomes. Moving forward, the chapter engages in the statistical interpretation of the model's results. Lastly, the overall performance of the model is evaluated. This evaluation assesses the model's reliability, accuracy and capacity to capture and predict the short-term resilience drivers that have been under investigation.

Chapter 6: Results and Findings represents the culmination of the analysis. This chapter offers an overview of resilience to the COVID-19 pandemic, revealing regional variations in resilience levels and the factors driving these changes in the short term. The implications of

the resilience model for policy and planning are thoughtfully deliberated, paving the way for actionable insight.

Finally, **Chapter 7: Conclusion** summarizes the key findings, underlining their implications. It underscores the overarching contributions of the dissertation to the body of knowledge and points towards potential avenues for future research.

The bibliography, Annex, list of figures, and tables enrich the study's academic integrity.

2 | Literature Review

2.1. Methodology

Within the context of the resilience notion, the foremost priority for achieving the ultimate goal of this thesis is to identify the key factors that predominantly influence the **short-term resilience** of regions to shocks. Given that the overarching objective is to develop a methodology for uncovering characteristics that may conceal potential vulnerabilities and weaknesses, which can subsequently be harnessed to enhance the economic and structural resilience of regions, it is imperative to assess existing indicators and previously explored areas. This process aims to bridge the gap between the best practices outlined in the existing literature and those aspects that remain inadequately addressed by current methodologies.

To reach this research objective, considering the level of maturity of the topic and the depth of analysis done on it, the most appropriate choice was to analyze and compare the various contributions given in order to identify differences and common results.

Although the thesis centres on short-term resilience to COVID-19, the conduction of an empirical analysis on a number of heterogeneous sources assessing different contexts becomes crucial in this phase. Indeed, it allowed the evaluation of different types of shocks in different places and different timeframes, pointing out the unique characteristics of countries and shedding light on the relatedness of their corresponding reactions and the types of shocks.

This **holistic analysis** facilitated a thorough examination of the unique aspects of each situation while delving into the underlying dynamics. The outcome of this endeavour was the evaluation of the main measures commonly used to analyze regional economic resilience and the development of a comprehensive table that systematically organizes and classifies all the indicators utilized in the selected articles, categorizing them based on areas, macro-areas and dimensions of resilience (see Table 2.1).

This categorization table was created after analysing numerous scholarly papers, enabling the formulation of a comprehensive and well-grounded definition of resilience components. References to the quantitative studies that were part of the analysis and related main information can be found in the Tabel A.1 in Appendix A.

The organic exploration of the literature and the subsequent creation of a clear categorization

of resilience areas served as a structured starting point and solid foundation for evaluating and selecting those indicators that should be considered to forecast the short-term resilience of a region. However, these indicators were still supplemented and enriched by the insights and patterns extracted from an organic analysis of both qualitative and quantitative studies in the field.

In the process of selecting sources, databases such as **Scopus** and **Web of Science** played a crucial role. These databases were leveraged to gather and examine various methodologies employed to measure the resilience and response to shocks in diverse regions and countries. These were then analyzed in relation to different areas, types of shocks, and historical periods. Additionally, the *snowballing method* was employed multiple times starting from exemplary cases from the literature, enabling not only the expansion of the knowledge acquired from initial readings but also the development of critical thinking and analysis.

In summary, the literature review was undertaken with the objective of providing an overview of the current knowledge and anticipating its future development through a comprehensive examination and extension of prior research. This will also aid in the appropriate selection of indicators that are best suited for a short-term perspective and that align effectively with the context of COVID-19. In this regard, the synthesized analysis of the literature, encapsulated in Table 2.1, served as a robust foundation for generating a new model with a conscious and well-supported selection of variables based on previous research.
It is crucial to stress that the methodical strategy used to conduct the literature review also entails an **iterative procedure**. In order to confirm and validate the study findings, the research was in fact continuously examined and frequently updated or amended over the course of the project.

2.2. Synthetic Measures of Resilience

Resilience characteristics are commonly assessed through **macroeconomic indicators** that reflect the performance of regions, such as changes in output or employment rates [113]. These synthetic indicators examine the levels of these variables before and after a shock or disturbance. While there are a few exceptions where similar measurements are incorporated into indicator dashboards or composite indexes, the employment rate or output rates are primarily utilized as **explanatory variables** for gauging the extent of regional economic resilience itself. For instance, resilience can be proxied with some comparison of the post-shock growth rate of the employment (or output) of the territorial unit considered and the pre-shock rate.

In empirical studies, the level of employment (or output) is treated as the *dependent variable*, while a set of other *independent variables*, believed to influence the level of employment or output, are considered as predictors. Such independent variables are different clusters of the areas categorized in Table 2.3.

Due to their central role in understanding resilience, employment and output rates are treated differently from other indicators outlined in the following sections. Therefore, in the following paragraph, a more extensive discussion will be presented on the key characteristics of employment and output levels in synthetically measuring regional economic resilience.

Employment vs. Output Measures

The vitality of the **labour market** serves as a reflection of the dynamism and adaptability of a region's employment landscape. The literature review unequivocally supports the connection between employment levels and regional economic resilience. Measurements of labour market vitality encompass various aspects, including absolute numbers or rates of employment and unemployment, as well as the temporal growth and development trends of these indicators.

In the literature, the use of absolute numbers to gauge labour market dynamism is infrequent, primarily because rates allow for comparisons across regions of different sizes. While employment rates undoubtedly serve as a pivotal indicator of economic activity, it is important to recognize that changes in these rates can stem from diverse factors. For instance, the impact of workers retiring earlier than anticipated in response to the shock, migration patterns driven by different employment opportunities, variations in the number of individuals accessing educational programs, and numerous other reasons can all contribute to shifts in employment rates.

By considering these rates, researchers can assess the overall impact of supply-side adjustments and demand-side shocks on the local labour market [83]. This approach enables a nuanced understanding of how the labour market responds to disruptive events and how it evolves over time.

On the other hand, the measurement of output rates in a regional economy primarily revolves around the **Gross Domestic Product** (GDP), which represents the total value of all goods and services produced within a nation's boundaries during a specified time period, typically a year. The GDP serves as a fundamental indicator for assessing the size and growth of an economy, providing valuable insights into its overall economic performance.

Given its ability to track changes in economic activity over time, GDP is widely utilized as a tool for evaluating and comparing the relative strength of different economies. It serves as a basis for understanding trends and patterns within an economy, making it an essential component in assessing resilience. By analyzing GDP, policymakers can gain crucial insights into an economy's ability to withstand shocks and recover from disruptions. Moreover, it helps identify potential weaknesses and strengths, providing a comprehensive view of an economy's capacity and performance and to formulate plans for building resilience.

For what concerns the choice between these two indicators to map the overtime response to shocks in regions, there is no one measure that is better *per se* than the other, but there are conflicting views about it.

Despite official statistics' preference for GDP, societal and political inclinations frequently regard employment as an indicator of an economy's health [114]. In the cases of countries with high institutional rigidity, GDP measures may better reflect economic fluctuations than employment. Considering the Italian experience, whose labour markets are rigid, the choice of GDP seemed more suitable to some scholars, specifically because the response of labour markets appears to be more uniform across regions as a result of institutional rigidities [24]. However, GDP does not take into account other factors crucial to resilience (see Section 3.1.1).

As a result, measuring the employment level may provide a more comprehensive view of regional economic dynamics and their ability to adapt to and recover from changes. This type of measurement goes beyond a simple output-based assessment and allows for the identification of strengths, areas for improvement and opportunities to promote economic resilience and the well-being of local communities.

2.3. Dimensions of Resilience

The utilization of employment and output level as explanatory variables for regional economic resilience falls short of providing a comprehensive understanding of the notion. Relying solely on these indicators may not capture the full extent of a region's resilience: while these synthetic measures are used for assessing how resilience varies from place to place, it is interesting to capture the distinct factors that have influenced such diversity in response.

Resilience encompasses a wide array of dimensions and factors that contribute to a region's capacity to withstand and recover from shocks or disruptions. Hence, a more encompassing approach is essential, involving a broader set of indicators and analyzing the interrelationships between different variables.

To address this need for a comprehensive analysis, this chapter aims to explore the range of resilience indicators adopted in the literature. The objective was to identify common characteristics among **areas** of indicators.

Through careful and systematic comparison, common **macro-areas** were identified, each approached differently by various authors and articles, reflecting their specific objectives while remaining relevant.

As a result of recognizing these macro-areas based on similarities, a natural differentiation emerged among three primary **dimensions** that are crucial for analyzing regional resilience: social, environmental, and economic-financial dimensions, as represented in Table 2.1.
This categorization establishes a framework for understanding the **multifaceted** nature of resilience and will serve as a roadmap for further investigation into its key components, facilitating the identification of the most relevant ones within the scope of this thesis.

DIMENSIONS	Relevance	MACRO-AREAS	AREAS
SOCIAL DIMENSION	92%	Community well-being	*Social fragility*
			Social cohesion
			Social integration
			Psychological factors
			Health
		Community composition & development	*Demographics*
			Population change
		Service availability	*Social services*
			Health facilities
			Digital opportunities
		Human capital	*Competencies*
			Digital skills
ECONOMIC DIMENSION	89%	Firms	*Financial solidity*
			Entrepreneurship
			Competitive profile
			Innovation
			Diversification vs. Specialization
			Agglomeration economies
			Trade dynamics
		Infrastructures	*Connectivity & access to digital network*
			Access to energy network
			Access to transportation network
		Institutions	*Governance arrangements*
			Financial condition
			Safety
ENVIRONMENTAL DIMENSION	14%	Pollution	*Air pollution*
			Water pollution
		Natural hazards	*Seismic risk*
			Hydrogeological risk
		Natural resources	*Soil condition*
			Nature capital

Table 2.1: Categorization of the dimensions, macro-areas and areas of regional economic resilience. Relevance is computed as the number of quantitative papers using the given dimension divided by the total number of papers in the analysis.

The first dimension of resilience, in terms of relevance in the studies considered, is the **Social dimension**, articulated in the following macro-areas.
The first macro-area is the level of **Community well-being**, which aims to measure the overall quality of life of individuals within a region and their physical, mental and social health. It assesses the differences between areas in terms of social fragility, social cohesion and social integration as well as encompassing aspects such as psychological factors and health.
The second macro-area defined is the **Community composition & development**, which focuses on analyzing the demographics and population changes within a community. It involves examining factors such as population size, composition, diversity, and migration patterns.
Part of the social dimension is also the **Service availability**, relative to the accessibility and adequacy of essential social services and facilities within a community. This includes assessing the availability of healthcare facilities, social services, and digital opportunities.
Lastly, this dimension is composed of the macro-area of the characteristics of the region's **Human capital**, which refers here to the general competencies and digital skills of individuals.
The social dimension is important for measuring regional economic resilience since a resilient region is not only measured in terms of its purely economic response to disruptive events but must be able to protect the well-being and security of its population. This implies the availability of essential services such as education, health, public safety, social cohesion and the like. Indeed, these are key factors for the attractiveness and economic competitiveness of the region and have a vital role to play in determining adaptability.

The second dimension of resilience by the incidence of analysis is the **Economic dimension**, which aims to identify the characteristics of regions contributing to resilience from an economic perspective. The areas of interest are multiple since they capture different and complementary aspects that build the economic structure of a region and they are categorized based on the key economic entities involved, namely firms, infrastructures and institutions.
The wider macro-area is the one related to region's **Firms**: a region's economy is undoubtedly shaped by the businesses operating in it, which may have different levels of financial resilience, entrepreneurship, competitive profile and level of innovation, that are fundamental building blocks in today's economy. Furthermore, in this macro-area are included the structural characteristics of the regional economy with respect to issues such as specialisation or diversification, the presence of industrial clusters and urban agglomerations and the relationship with the outside region, i.e. import and export dynamics.
Infrastructures also play an important role, as structural differences between regions are an important discriminator in their response to shocks and their ability to cope with the changing environment in which they are embedded.
Finally, **Institutions** are key drivers in determining the economic dimension of resilience in terms of policy, arrangements and conditions inherent to the financial, fiscal, governmental and security situation.
Undoubtedly, the economic dimension is crucial when analysing the economic resilience of a

region. The objective is to verify that the region under analysis has a competitive economy that is able to withstand shocks and adapt to change. This requires a strong business and industry base, the quality of infrastructure and services, the availability of financial and technological resources, and an investment-friendly environment.

Lastly, a third dimension identified in the literature, but present in far fewer studies than the previous, is the **Environmental dimension**. Indeed, it is an underestimated dimension in studies of a region's resilience to economic shocks, more often confined to studies investigating natural disasters.
This dimension can be articulated into four macro-areas which investigate the level of **Pollution**, be it of air or water; the incidence of **Natural hazard**, which encompass the assessment of seismic and hydrogeological risk; the magnitude of **Natural resources**, in terms of soil condition and the area's nature capital; finally, the management of **Waste** policies.
Despite the lack of interest in measuring this resilience dimension in the literature reviewed, it is considered to be of significant importance. A region is potentially more resilient than another if it is able to promote sustainable production and consumption patterns and measures that limit negative environmental impacts by the businesses and people that inhabit it. Moreover, the link between environmental resilience and economic resilience is very close. A region that cannot cope with environmental challenges, such as natural resource scarcity and climate change, is likely to be more vulnerable to economic disruptions. This risk is accentuated in the case of regions whose economies are highly dependent on natural resources, for example, regions that are heavily dependent on mining, agriculture or fisheries. If these natural resources are not managed sustainably, they can be over-exploited or depleted, with negative consequences for both the environment and the economy, especially in the long term. In addition, promoting environmental resilience can create new opportunities in the strictly economic sphere, such as sustainable technological innovation and the valorisation of ecosystem services. Such opportunities have the potential to help stimulate economic growth and employment while promoting environmental sustainability.

Having presented the dimensions and macro-areas identified by the literature review, a detailed discussion of the areas of resilience is provided in the following paragraphs, subdivided by dimension.

2.4. The Social Dimension

The social dimension is used in measuring the economic resilience of a region to varying degrees depending on the **type of shock** in question. Indeed, while it is a fundamental and universally recognised dimension adopted by studies of resilience to natural disasters, it does not have the same prominence in the case of studies of economic downturns. In fact, studies dealing with the response to natural disasters always consider this dimension of analysis in a balanced manner

across the various macro-areas discussed. The same cannot be said in the case of economic shocks and recessions, whose studies treat this dimension as marginal except for a few exception areas.

Table 2.2 provides a breakdown of the percentage incidence, calculated as the number of papers adopting the area in question divided by the total number of documents analysed or the total by shock category.

In particular, within the macro-areas of community well-being and human capital, the use of the two areas *Social fragility* (adopted in 31% of total studies under discussion) and *Competencies*(adopted in 47% of the cases) emerge respectively.

The remaining areas and their respective macro-areas are used in a much lower percentage in the studies dealing with recessionary shocks, or not even present in any of the studies belonging to this category. Incidence rates rise substantially in the case of studies on natural disasters, which shows how the social dimension has often been related in the literature to calamities impacting an area without discounts. Whereas, the dimension of social impacts is, probably incorrectly, at least partially underestimated in the case of economic shocks.

MACRO-AREAS	AREAS	Relevance	Relevance in economic shocks	Relevance in natural disasters
Community well-being	*Social fragility*	*31%*	*19%*	*83%*
	Social cohesion	*19%*	*15%*	*33%*
	Social integration	*17%*	*12%*	*33%*
	Psychological factors	*3%*	*4%*	*0%*
	Health	*8%*	*0%*	*50%*
Community composition & development	*Demographics*	*17%*	*12%*	*50%*
	Population change	*14%*	*4%*	*50%*
Service availability	*Social services*	*6%*	*0%*	*17%*
	Health facilities	*11%*	*0%*	*50%*
	Digital opportunities	*3%*	*0%*	*0%*
Human capital	*Competencies*	*47%*	*42%*	*83%*
	Digital skills	*3%*	*0%*	*0%*

Table 2.2: Percentage incidence of areas in the literature of the social dimension of regional economic resilience.

2.4.1. Community Well-being

The first macro-area, named **Community well-being**, is measured by the following areas:

1. Social fragility;
2. Social cohesion;
3. Social integration;
4. Psychological factors;
5. Health.

Social Fragility

Social fragility indicates a region's vulnerability to perturbations and shocks in terms of a multiplicity of aspects and situations, which appear to be pervasive in the social fabric. Measuring social fragility involves assessing personal security, poverty rate, crime rate, structural dependency, income inequality and other factors that influence a region's ability to cope with and overcome destabilizing events. This indicator is adopted by 31% of the total papers but by 83% of the studies on resilience to natural disasters and only 19% of studies on shocks of an economic nature. Scholars who adopted this indicator have developed specific approaches and used a variety of proxies to assess this complex concept.

In their study on a multitude of natural disasters (abundant rainfalls, frequent thunderstorms, hurricanes that bring damaging winds, coastal and inland flooding, catastrophic storm surge, and coastal erosion) Cutter et al. proposed the usage of **Gini coefficient** as a proxy for assessing income inequality in the perspective of social fragility [32]. The Gini coefficient serves as a descriptive measure of inequality within a specific distribution, in this case, the income distribution of a region and it is computed as the difference between the ideal distribution (income equity) and the actual distribution in the region. Such disparities have the potential to influence economic resilience significantly. This indicator is also used for the same purpose in other several studies (e.g., [110]) and the reason behind this choice is that, when compared to other measures, the Gini coefficient results in easier interpretation [116].

However, it is important to note that the Gini coefficient may have some limitations in providing a complete representation of economic inequality, as it is based solely on income distribution and does not take into account other socio-economic factors. Indeed, [116] also uses the Gini coefficient for measuring social fragility but extends the measure by also considering additional factors such as the **inequality in home ownership** and the **property crime rates**. These proxies highlight the economic and social inequalities that can hinder a region's economic resilience in the face of disruptions. Another interesting contribution is offered in [73], in which

the same objective of relating social fragility to income inequality is explored, although not using the Gini coefficient. The ratio of the income of high-income households to that of low-income households is adopted as a proxy for income inequality within a region. This indicator provides a measure of income concentration among segments of the population, offering an indication of economic inequality that may influence the reaction to shocks.

Other authors, on the other hand, have declined social fragility in their analysis of **regional poverty**. Indeed, in [25] the importance of considering vulnerable populations and individual capacity as indicators of social fragility is emphasized. These aspects reflect the presence of disadvantaged groups within a region and their ability to cope with negative economic events. The inclusion of these proxies in the assessment of social fragility contributes to a more comprehensive understanding of regional economic resilience. In some studies, also **poverty incidence** has been considered a crucial measure of social fragility [53]. Proxies of this kind reflect the presence of individuals and households that are in extremely precarious economic conditions and may be particularly vulnerable to crisis. Finally, Azzone et al. in their study on the recovery of Italian territories, adopted a different perspective than previous studies and the social fragility of a territory is approximated using the **structural dependency index** [10]. This index assesses the sustainability of a territory's population structure and measures the economic burden on the potentially labour-active segment of the population, responsible for the livelihood of the young and the elderly. High values may indicate possible criticalities in terms of demographic balance and imply significant challenges in terms of a region's vulnerability to economic shocks.

Social Cohesion

The area **Social cohesion** refers to the presence of social ties within a region and aims at identifying elements of civic culture. It is adopted in several studies, dealing with shocks of various natures, and sometimes it is declined in the *presence of the third sector*, with the same intent of measuring a region's capability to nurture solidarity process and cohesion between inhabitants. For these reasons, the measurement of social cohesion entails examining factors such as mutual trust, community cohesion, civic participation, the network of social relations and cooperation between individuals and groups.

In the analysis of resilience to natural disasters by Cutter et al. in 2008, several indicators were identified for this area, including religious organisations and social networks [31]. They reflect the strength of relationships within society, the active participation of citizens in the region and the presence of organisations in the area that promote mutual support and cooperation across a variety of aspects. In the subsequent study published a few years later [32], these indicators were further developed to include political involvement, religious social capital, civic involvement and involvement in social activism, declined, for example, in the electoral participation rate in elections, the percentage of religious adherents, the number of civic organisations and social activism organisations. In this way, the authors promised to measure the involvement and

active participation of citizens in the political, religious, civic and social spheres. The importance of citizens' active participation in politics is also recognised in [36], an empirical study on resilience to shocks of an economic nature in Italy, which adopts precisely electoral participation in referenda as a proxy for social cohesion. Such proxy can reflect citizens' interest and engagement in democratic participation and can subsequently materialise in the level of awareness and involvement in dealing with shocks of any nature.

Again, Sherrieb et al. in measuring the engineering resilience of Mississippi counties in the face of Hurricane Katrina, consider factors such as social support, social participation and the presence of third-sector organisations to be among the key promoters of resilience [116]. Mazzola et al. in [95], for instance, have analyzed the Italian regions' resilience to the Great Recession by measuring the number of social cooperatives per inhabitant.

Interesting are also some of the most recent contributions to the analysis of resilience, such as the contribution of Faggian and Ascani in 2021, who examined productivity and post-COVID-19 resilience focusing on analysing the social structure in terms of the presence of social networks within a region and organizations belonging to the third sector, highlighting the importance of social connections for resilience [48]. Similarly, in [10], the presence of the third sector, measured by the incidence of employment in third sector organisations (classified as legal forms of non-profit institutions such as social cooperatives, associations, foundations - non-banking - and other legal forms of non-profit institutions) on the resident population at the Italian provincial level, is considered as a factor leading to an increased ability to mobilise and respond to disruptions.

Social Integration

The last area identified for the social dimension of resilience is the level of **Social integration**, which indicates the degree of inclusion and social cohesion of heterogeneous groups within a region. Its measurement may cover different aspects, such as the absence of racial discrimination and integration of different ethnic groups, the inclusion of minorities, as well as gender equality issues.

Some studies have shown interest in gender equality as a proxy for social integration, looking at the percentage of female labour force participation (see [32]). According to scholars, gender disparity in the labour market is a way to capture behavioural modes inside regions, having the potential to shape the resilience attitude [54].

[105] not only looks at the gender gap but also at the **discrimination of youth** by distinguishing the analysis of the level of general employment to the employment rate of the youth segment of the population. Other studies, on the other hand, interpret integration more in terms of the social inclusion of **immigrants** in the area of interest. Thus, there are those who look at the percentage of the immigrant population (e.g., [73]) or, more interestingly, at the wage gap (e.g., [10]), or even at the different levels of education (e.g., [116]).

Psychological Factors

The area of **Psychological factors** mainly includes the expectations, perceptions and confidence of local agents in reacting to the shock. This is a relatively unexplored aspect in the literature, although, according to several authors, it deserves to be considered an explanatory factor in its own right [92].

According to [99], decisions regarding new investment and job creation will be hampered if regional expectations and confidence, thus psychological traits, are already low and fragile prior to a shock. This will serve to amplify the first effects of the shock, which could then further depress expectations and confidence. A business community and workforce, on the other hand, who have a positive view and trust in the fundamental health of the local or regional economy, will be more likely to take action in anticipation of an early upturn and return to growth. Such optimism might therefore provide the local economy resilience and be self-fulfilling.

Health

Lastly, the **Health** area refers to multiple aspects of the well-being and health of the population living in a region. It goes hand in hand with the availability of *Health facilities*: in fact, they can be considered complementary and sometimes partially overlapping areas in terms of meaning. In this specific case, the driver under discussion refers mainly to the state of health, mortality rates and the like.

Within the bounds of this research, it is only analysed as an impactful area in quantitative studies investigating resilience in the case of natural disasters [31, 32, 110, 116]. The reasons behind this lie in the fact that the level of health and wellness influences a region's ability to recover in the face of an emergency, since a healthy population has more resources to deal with it in the most resilient way. In contrast, it is not considered a resilience driver in the case of papers dealing with recessionary shocks.

2.4.2. Community Composition & Development

In this macro-area, a deeper examination is provided of the population of a specific region, encompassing both its current features and temporal evolution. The analysis includes the domains of *Demographics* and *Population Change*.

Demographics

The **Demographics** area provides information on the structure and characteristics of a region's population, studying factors such as size, age, gender, ethnicity, family structure and the like.

Again, it is most frequently used in papers on natural disasters, as in [84] and [88] where multiple facets are taken into account (age, race and ethnicity, family structure), and considered

less relevant in the case of economic shocks, despite some exceptions. For instance, in [49], the population size is considered among the variables that play a fundamental role in measuring regional economic resilience. However, in this case, the population size is mainly interpreted as a signal of agglomeration economies, rather than an indicator in the field of community composition.

Instead, other proxies result to be more related to the scope of the area, as intended in this classification. The main example is the percentages of age groups of the population, as adopted in [32, 59, 83], whose aim is to capture how the age structure of a region's inhabitants can influence its resilience. In particular, the underlying idea is that a region with a high proportion of young people has demographic potential for economic development and innovation and in parallel requires greater investment in education and development services; likewise, a high proportion of elderly people results in effects that may influence resilience, as it may result in a greater challenge for social and health care services.

Population Change

Population change, particularly with reference to migration flows between different regions or even countries, becomes a driver of resilience when interpreted with respect to the **change in human resources** it brings about.

This indicator is also scarcely employed in the literature and its application is almost exclusively restricted to studies of natural disasters. In fact, it often happens that large emigration flows follow catastrophic events. Giannakis et al. in their study on the resilience of European regions to the Great Recession, demonstrated that the average annual net migration change has been the factor with the most significant positive effect on regional resilience [59]. Similarly, in [32] it is illustrated that place attachment, measured with the percentage of the population born in an area that still resides in the same area, has a positive correlation with resilience and, in parallel, a high net international migration reduces resilience. Other authors have not focused exclusively on migration flows to measure the population change, e.g., Capello et al. combined the regional migration rates with the regional population growth, whose estimated values depend also on the crude birth and death rates [21].

2.4.3. Service Accessibility

The second macro-area defined is **Service availability** and comprehends three areas:

1. Health facilities;
2. Social services;
3. Digital opportunities.

While distinct in nature, all of these domains reflect the potential for individuals in a given region to readily access essential aspects of life: healthcare availability through the presence of health facilities, work and education accessibility through digital opportunities and the possibility of receiving support through the presence of social services.

Health Facilities

The proximity to **Health facilities** provides quick access with reduced transport times to the medical care needed in the event of an emergency, illness or accident. In addition to the more general benefit of improving the quality of life of the region's population and the related economic impacts, accessibility to hospitals can make a difference in certain situations, which is why it is recognised as a driver of resilience on its own.

As a matter of fact, it is not considered among the areas touched in the case of studies dealing with economic shocks; instead, it is adopted in several of the analyzed studies on natural disasters and calamities. For instance, Cutter et al. in [31] measure the presence of lifelines and other critical infrastructures; in [32], the same author goes deeper in detail looking at the medical capacity through the number of hospital beds per 10,000 inhabitants. Similarly, [88] adopts the indicators of the number of health service points together with the number of medical personnel to measure the resilience of Maitara Island to natural disasters and climate change. Again, [110] uses the proximity to health infrastructures as one of the indicators to investigate the relationship between resilience and sustainability; as well as [10] who considered the distance to hospital emergency facilities as a driver of resilience to the COVID-19 pandemic.

Social Services

With regards to **Social services**, the significance of the area is to look more generally at the support and development of public services that regions are able to provide to their citizens.

The analysis in the literature utilizes different approaches and indicators based on varying research objectives and motivations, as exemplified by the following examples. In [10], an index was constructed to assess the capacity for service delivery at the municipal level by considering the resources required to bridge gaps in social services at the municipal level. On the other hand, [25] takes into account the presence of public services, focusing on a broader range of activities offered to citizens. Nonetheless, this area remains relatively unexplored in terms of research.

Digital Opportunities

The availability of **Digital opportunities**, demonstrates a region's ability to embrace innovative and flexible working practices in response to changing conditions. Examining the opportunities available for occupational and working-hour flexibility of employees, as well as remote employment opportunities, is necessary to measure this area.

As can be easily intuited, this is not an area that has wide relevance in today's literature dealing with regional economic resilience. In fact, most of the studies analysed are concerned with examining the short- or long-term response to shocks that occurred prior to the current technological evolution that has provided for the spread of digital tools and capabilities that enable working outside the employers' premises. Although some qualitative papers highlight its importance [48, 92], quantitative studies on the subject are scarce. The exception in our analysis is [10], which provides an interesting positioning of Italian territories in terms of the socioeconomic impacts of COVID-19. Here, remote working opportunity is seen as an important lever against disruption of economic activities, that promotes faster recovery and thus represents an influential resilience driver discriminating between regions.

2.4.4. Human Capital

The macro-area defined **Human capital** aims to attempt to measure the value of the people who inhabit a region. This value derives from the knowledge, skills and abilities of people.

Human capital is universally recognised as a driver of economic productivity and sustainable growth, in the sense that it is the region's human capital that will lead to greater adaptability to new technologies, improved performance, increased innovation and better opportunities. In the literature, it is undoubtedly also recognised as a driver of resilience, in different facets but certainly held in high regard. It is measured through two areas:

1. Competencies;
2. Digital skills.

Competencies

Approximately half of the studies investigated the correlation between the population's **Competencies** and the level of resilience, almost irrespective of the specific type of shock being discussed. Although opinions differ as to its relevance, it is generally considered a valuable area of analysis. Pontarollo highlighted the deep importance of a skilled labour force to deal with shocks [105]. This study demonstrated that a more educated workforce is also more competitive in the labour market and this increases employability, contributing to general progress in regional economies and positive spillover phenomena.

Similarly, according to Krugman in [85], education shapes the performance and the adaptability of a region's economy since a highly skilled and competent workforce not merely affects how businesses use labour but also gives the local economy more flexibility to recover from significant shocks.

When it comes to indicators used to assess people's competencies, the selection often depends on data availability, and in general, authors tend to rely on established metrics related to educational

attainment within a region. Often the interest lies in various measures of the percentage of the population with tertiary education (e.g., [42, 54, 59]). More original, on the other hand, are the indicators used to measure more general competencies, which go beyond the "formal" competencies. In this respect, an interesting example is provided by [116] which uses as a driver for resilience the percentage of creative class occupation. A region's capacity to attract and hold onto a talented and creative workforce over the long term is undoubtedly one of the primary determinants of regional resilience and recovery, according to Glaeser's research on Boston's response to numerous shocks over a 250-year span [61, 92].

Digital Skills

The **Digital skills** area represents a due distinction from the more generic category of competencies, as digitalisation is transforming the way people live, interact and work. These skills are indeed necessary for social participation and digital inclusion.

Digital skills were defined in 2006 by the European Parliament as "the ability to use information society technologies (IST) for work, leisure and communication with familiarity and critical thinking". Although the significance they may hold, indicators related to digital skills are not commonly included in the literature when measuring regional economic resilience, with the exception of [10]. As with the *Digital opportunities* area, the rationale may be inferred from the fact that these are skills that have only relatively recently gained significant importance.

2.5. The Economic Dimension

The second dimension in terms of relevance, is the **economic** one, which relates to the features of the infrastructural assets and production structure that are essential to the competitiveness and expansion of the region.

This dimension appears uniformly deployed to address both economic crises and natural calamities in some macro-areas, while highly divergent in others, as it can be observed in Table 3.1.

When comparing the areas utilized for the two clusters of papers, it can be noted that the most often used indicators for economic recessions fall within the macro-area designated as **Firms**. In this context, the term "firms" refers not only to the specific characteristics of these legal entities as actors in regional economies, but takes on the broader explanatory meaning of the very composition and arrangement of sectors within an economy, i.e. the industrial structure. Indeed, the **industrial structure** of an economic region plays a key role in identifying vulnerabilities and assessing interdependencies. In fact, it provides valuable guidance to policymakers in making strategic decisions to improve resilience and promote long-term sustainable economic growth.

MACRO-AREAS	AREAS	Relevance	Relevance in economic shocks	Relevance in natural disasters
Firms	*Financial solidity*	*17%*	*12%*	*17%*
	Entrepreneurship	*11%*	*8%*	*33%*
	Competitive profile	*19%*	*12%*	*17%*
	Innovation	*33%*	*31%*	*33%*
	Diversification vs. Specialization	*69%*	*69%*	*50%*
	Agglomeration economies	*47%*	*46%*	*33%*
	Trade dynamics	*19%*	*27%*	*0%*
Infra-structures	*Connectivity & access to digital network*	*11%*	*0%*	*50%*
	Access to energy infrastructure	*3%*	*0%*	*17%*
	Access to transportation network	*25%*	*19%*	*50%*
Institutions	*Governance arrangements*	*22%*	*15%*	*50%*
	Financial condition	*11%*	*4%*	*50%*
	Safety	*8%*	*0%*	*50%*

Table 2.3: Percentage incidence of areas in the literature of the economic dimension of regional economic resilience.

When examining resilience to natural disasters, the focus primarily revolves around two macro-areas: **Infrastructures** and **Institutions**. Conversely, these aspects are inadequately addressed in the other category of studies analyzed.

On one hand, analyzing the infrastructural background of a region is crucial to ensure that systems are constructed to withstand and recover from the effects of natural hazards. Additionally, it aids in identifying vulnerable areas and prioritizing mitigation efforts.

On the other hand, institutions play a critical role in assessing natural disaster resilience and facilitating the recovery process from such catastrophic events. Given their significant impact and influence on how societies prepare for, respond to, and recover from disasters, institutions offer practical possibilities to address and cope with the resulting effects.

2.5.1. Firms

As the primary actors impacting and driving the regional economy, **Firms** represent the first macro-area for examination. Studying how businesses operate, generate value, overcome challenges, and contribute to local prosperity provides crucial insights. These insights can be used to develop policies and targeted support programs aimed at enhancing regional resilience in the face of future crises.

The following areas are explored:

1. Financial solidity;
2. Entrepreneurship;
3. Competitive profile;
4. Innovation;
5. Agglomeration economies;
6. Diversification vs. Specialization;
7. Trade dynamics.

Financial Solidity

Financial solidity assesses the financial condition of firms within a specific region, shedding light on their economic management practices and interactions with the external environment. By providing insights into the efficacy and efficiency of firms' financial management techniques, it facilitates well-informed decision-making.

The literature on regional economic resilience has seen contributions from several authors in the area of financial resilience. Di Caro in [36] examined the economic resilience of Italian regions using as a proxy the average interest paid by companies to obtain a specific financing transaction. Differently, [10] looks at the percentage of companies that indicate a lack of financial resources as an obstacle to their success: the availability of funds permits the activation of the investments that may be necessary for the ecological transition and digitisation, and consequently has a direct impact on the competitive capacity of the company and in turn of the territory.

Moreover, [116] primarily concentrates on measuring the net business rate gain or loss over the course of a year. Differently, while Martin and Sunley examined the debt structure [92], in [65] different indicators are combined, namely the liquidity ratio, loans to firms, return on equity, and value-added per capita. Lastly, a special case is [60], in which regional resilience to economic crises is investigated considering the level of investments expressed as a percentage of gross fixed capital formation to gross value added (% of GFCF to GVA).

Hence, the complexity of financial resilience and the significance of taking into account many factors in its evaluation are reflected in the wide spectrum of indicators utilized by these authors to quantify financial strength in the assessment of regional economic resilience.

Entrepreneurship

Entrepreneurship refers to the tendency to conceive and create new business ventures, taking responsibility for managing and operating them and willingly accepting the associated risks. It is indicative of high responsiveness to change and evolving trends and is thus often associated with good and prompt adaptation to new circumstances.

The entrepreneurial mindset fosters a culture of proactivity and continuous learning, training the ability to modify strategies when necessary and identify emerging opportunities on which to capitalize. Indeed, in times of economic or industry-wide shocks, entrepreneurs are often at the forefront of innovation and recovery.

Overall, this aspect is considered in [48] and [92] as the entrepreneurial spirit is believed to foster economic progress: the determination and passion characteristic of it fuels motivation and persistence in the face of obstacles.

Moreover, the increasing relevance of this factor is confirmed by Iacobucci and Cherubini's creation of a composite index of *Entrepreneurial Ecosystems*, in the attempt to measure the relation between the strength of entrepreneurial ecosystem at the local level and the resilience to economic shocks [79]. The authors have demonstrated that strong and vital entrepreneurship has a positive impact on the capacity of provinces (NUTS3) to resist shocks and recover from crises.

Competitive Profile

The **Competitive profile** highlights specific aspects of firms that set them apart, granting them a competitive edge over similar firms in other regions and contributing significantly to the region's assets. When combined with a firm's entrepreneurial spirit and strategic vision, these resources, whether tangible or intangible, create a winning cycle that propels the region towards greater success and prosperity. Consequently, this fosters overall regional growth and resilience in the face of shocks by fostering innovation and entrepreneurship, driving economic expansion, and attracting investments.

The literature exhibits significant heterogeneity of indicators concerning the competitive profile area. In [10], the significance of measuring the competitive profile of companies as drivers of resilience is acknowledged. They adopt a synthetic competitiveness index as a proxy, which takes into account multiple factors such as cost competitiveness, gross profitability, the share of exported turnover, and the share of innovative companies. Still from the perspective of com-

petitiveness, the size of the enterprises is considered. According to [58], a firm's capacity to adapt to change is influenced by its size. Even if increased scale results in specialisation and higher concentration, larger organisations and sectors may be better able to weather severe transformations. Similarly, [120] showed that major businesses recovered far more quickly from the Northridge earthquake compared to smaller businesses. However, there are divergent opinions on using the size of firms as a measure of resilience. For instance, Tsiapa et al. explored Eastern European countries' reaction to the Great Recession [122] and found that Small- or medium-sized enterprises (SMEs), which may represent the backbone of the economy in certain regions, possess various advantages over larger firms. Due to their flexibility and adaptability to change, SMEs demonstrate higher capacities to absorb and respond to shocks, thus exhibiting greater resilience. Their ability to stay competitive in the face of shifting market trends, advancing technologies, and emerging management practices allows them to endure economic collapses and other challenges, which contrasts with other studies that suggest greater size leads to greater resilience.

Innovation

Innovation plays a pivotal role as a resilience area, empowering a region to thrive amidst the ever-changing landscape of economic, technological, and social challenges. By encompassing diverse manifestations, such as novel technologies, products, processes, and business models, innovation becomes a formidable force, impacting both corporate entities and public and private organizations.

In the realm of quantitative research, innovation emerges as a highly sought-after indicator to gauge resilience, featuring prominently in approximately one-third of the analyzed papers. It stands as a potent force, capable of mitigating the impacts of shocks and presenting new avenues for an efficient recovery. Remarkably, this holds true regardless of whether the studies focus on natural disasters or economic downturns. The significance of innovation transcends traditional boundaries, making it an indispensable component in bolstering a region's resilience and adaptive prowess in the face of dynamic challenges.

In particular, Simmie and Martin identified innovation as a crucial adaptive behaviour for regional economies, made up of agents who are constantly learning and adapting to their environment [117]. Indeed, according to the authors, flexible and creative response to shocks depends on the innovative capacity of local firms.

Due to its function in aiding the region's industrial structure's adaptability, innovation is significant in the reorientation and renewal components of resilience [15] and it can be considered as the "evolutionary fuel" of complex systems like regions [18, 29].

The role of innovation has been investigated in a comprehensive way in [18], which demonstrates empirically that the attitude toward innovation of regions is strongly related to their resilience

to shocks. Results showed that European NUTS2 regions classified as leaders in innovation, immediately before the Great Recession started, had a significantly higher probability to withstand the crisis or to recover from it within three years. At the same time, regions with the lowest levels of innovative capacity at the time of the crisis were the least equipped to respond to it. Hence, innovation at the firm level is not only associated with advantages in the moment of shocks, but it is a useful asset and baggage to better face any future shocks [122].

The majority of the studies that adopt innovation as a resilience driver uses "output measures" of innovation, such as patent-based measures, like the number of patents [13, 65, 105, 110]. Since innovations are protected by patents, they are employed as a proxy for innovation, however, there are some issues associated with this measure: not all innovations are patented, this may lead to an underestimation of the innovation in the region; patenting is not neutral to industries and/or geographical areas, for example in the pharmaceutical industry firms patent much more than in technological industries. Other recurring measures are, instead, "input measures" such as the R&D based-measures, as R&D expenditure [21, 122] or R&D employees/Total employees. Finally, some scholars decided to measure innovation by having a look at the universities' research activities [42, 73] and entrepreneurs making use of endogenously created knowledge for the commercial exploitation of intellectual property rights.

Agglomeration Economies

Agglomeration economies refer to the phenomenon where businesses cluster together in a specific geographic area, developing a robust and efficient physical and knowledge network. This occurs when multiple businesses choose to locate themselves in close proximity, leading to favourable externalities for these enterprises [106].

According to Cohen et al., agglomeration economies can be divided into two main groups, each having a unique type and extent of economic influence: **localized economies** result from the concentration of a specific industry in a limited area, while **urbanization economies** arise from the high density of economic activities in the region [28]. The advantages of localized economies stem from cost reductions for businesses located close to others in the same industry, allowing them to share and combine resources and create a specialized workforce specific to their sector. The benefits of urbanization economies come from cost reductions experienced by companies located near others operating in different industries, as they have easier access to a wide range of goods and services (such as accounting, design, and legal services) beyond their own field [28].

In this subsection, the focus is on urbanization economies, while localized economies will be explored in the subsection related to the *Diversification vs. Specialization* indicator (see Section 2.5.1).

The area of urbanization economies is one of the most extensively studied, being present in about half of the articles, with a significant presence both in the case of economic shocks (46%)

and natural disasters (33%), where having a solid network to rely on becomes a differentiating factor for the potential recovery of the region.

Overall, the positive effects of urbanization economies can be summarized in three dynamics: **sharing**, **matching**, and **learning**. A diverse and extensive labour pool allows businesses and employees to better match their skills and needs and share reliable resources when required. Moreover, a broader customer base facilitates businesses in learning about cutting-edge technology and management techniques [41].

However, the advantages associated with urbanization economies are not without challenges. According to Simmie and Martin, increased connectedness tends to reduce the system's adaptability to changes, negatively impacting its resilience: "The more internally connected is a system, the more structurally and functionally rigid and less adaptive it is" [117]. Consequently, connectedness is considered inversely proportional to resilience.

One of the most explored factors to assess this area is the structure and openness of **regional knowledge networks**, as found in [13, 15, 35, 49]. The internal organization of knowledge networks and their accessibility to the outside world influence how sensitive a region is to shocks and how capable it is of finding new development pathways. Certain network topologies are more susceptible to the loss of a node and become completely paralyzed if one of them fails, while some network structures are naturally better capable of inducing drastic changes and effectively sustaining them. In general, a tightly knit core improves communication and coordination among members, reducing the likelihood of opportunistic behaviour and favouring control and efficiency.

However, in line with Simmie and Martin, Boshma reports that dense local network structures lead to lower adaptability: excessive local connectivity can hinder renewal, causing the region to suffer from a lack of recombination possibilities and making it more susceptible to shocks [15].

On the other hand, as also highlighted in [48], the absence of internal cohesion and systemic connectivity in cities with open and disjointed knowledge network structures creates obstacles to the transmission of local knowledge, resulting in weak or nonexistent collective learning. However, the fragmentation of local networks can offer a wide range of diverse knowledge sources with a high potential for innovative development routes, favouring long-term adaptability.

Another indicator frequently adopted in this area is **population density** (see [13, 39, 42, 54, 88, 105]), which, being relatively independent of the surrounding industrial structure, can be considered indicative of urbanization economies [20]. While in some cases, the correlation between crisis impact and population density was found to be nonsignificant [42, 103], in [54], population density is positively correlated with resilience. Conversely, in [39, 83], the results show a greater crisis impact in more densely populated areas, which could be probably related to the specific social traits of densely inhabited locations. In [95], localized economies are taken into account using *Gross indices of urbanization economies*, as the share of the most populated

municipality over the total provincial population and the percentage of immigrants over the total number of residents were also used, but they result to have no discernible effect.

According to Faggian and Ascani in [48], although urban areas offer more opportunities for digitalization and better access to services than rural and peripheral areas, they are also more likely to experience pollution, crime, and congestion compared to semi-dense and non-urban areas. As a result, agglomeration dynamics can result in a complicated mix of benefits and drawbacks for productivity development that, during a crisis, can also interact in various ways with a region's resilience.

Diversification vs. Specialization

Another critical area, deemed as a driver of resilience in approximately 69% of the analyzed studies, pertains to the industrial structure of the region concerning the degree of **specialization** or **diversification**. The considerable significance of this indicator in the literature is not markedly differentiated based on the type of shock under examination.

This indicator refers to the composition and diversity of the industries present in a region. A specialised industrial structure indicates that the region has a significant concentration of economic activity in one or a few specific industries. In other words, there is a predominance of a specific sector or a few sectors within the regional economy. On the other hand, diversification means operating in multiple industries, thus a diversified industrial structure indicates that the region has a balanced presence of different economic activities in various sectors. This means that the regional economy is less dependent on a single sector and has a wider range of industries represented.

The level of diversification or specialization of regions is measured differently by the authors, but always with the same aim of understanding the level of dependence on certain sectors, with particular emphasis on manufacturing, and what kind of diversification, if any, is involved, i.e. related or unrelated. Some common indicators in the literature include:

- the sector's share of economic activity relative to the national average;
- the distribution of economic activity across the number of sectors in the region;
- the sectoral composition of employment in the region;
- the export sector diversification of regions.

One specific indicator is the **Herfindahl Index** (HI), which is the weighted sum of the market shares of all players. Adopting the squared market shares, higher weight is given to industries with larger market shares. This index ranges from 0, indicating complete diversity, to 1, indicating complete specialization. Another way to view this is in terms of **concentration**, where

an increasing HI signifies a more concentrated workforce in fewer industries. Overall, business diversity can be assessed by looking at all the sectors present in the region and each sector's share of that total, whether it be in terms of revenue, workforce, or output [116].

While its relevance is undisputed, the role of specialisation (or diversification) in regional economic resilience is not. The question to be asked is whether specialisation is a **positive or negative driver of resilience** and economic development. According to some economists, specialisation is one of the main drivers of a region's economic growth (see [118]); conversely, there are those who argue that it is precisely diversification that confers reduced risks and increased and stable growth prospects (see [70]). The underlying idea is that a diversified industry structure may allow a region to **spread risk** and thus better withstand a shock since the different sectors involved may be affected differently, allowing negative and positive effects to counterbalance each other better than with a less flexible specialised structure. According to this perspective, an economic region with a highly specialised structure might be more vulnerable and unstable in the event that the shock hits hard the sector on which the region's economy rests and in the event that the other economic sectors have such limited scope and relevance that they are unable to provide a cushion [93].

In other words, even though a certain degree of specialisation can often be considered to foster growth due to increased competitiveness and externalities, it may leave regional economies exposed to business cycles that impact the specialised sectors [35, 82].

However, empirical analyses have in some cases shown otherwise. Di Caro et al. found that regions specialised in highly productive activities are more likely to withstand the impact of the economic crisis [35]. Also according to [59], the specialisation of regional economies can positively impact their resilience. Other studies, instead, stated that the specialisation index failed to provide statistically significant results of its capacity to influence resilience [82].

More interestingly, several studies show that specialisation is not "good" or "bad" for resilience *per se*. Rather, its impact varies depending on the specific industries being considered. The assumption is that some economic sectors are more susceptible to cyclical economic fluctuations than others and, as such, are more affected by economic crises [99].

Studies on the subject show that the **manufacturing** and construction industries generally seem to suffer more than the service sector during shocks. In fact, the service sector appears to be more flexible and resilient than the manufacturing sector [86].

Lagravinese offers interesting insights into the topic of the relationship between specialisation in certain sectors and resilience. In his study on the response of Italian regions to the economic crises that occurred in Italy between 1970 and 2011, he found that Lazio, a region most specialised in the service sector, was more successful than other regions in mitigating the effects of the crises [86]. According to the author, the service industry has been increasingly important in sustaining competitiveness, especially after 2000 with the advent of the digital era and global-

ization. In this regard, Lagravinese's findings on the Piemonte case, as illustrated in his work, are a prime example. This region serves as the headquarters for FIAT, the largest automobile manufacturer in Italy. This region was among the richest in Italy during the 1980s automotive boom, but during the past years, the region has declined as a result of the automotive sector crisis. This case emphasizes how high specialisation in manufacturing can be deeply ambivalent: regional specialisation in a particular industrial sector could be frequently advantageous during times of economic expansion, but it can also be detrimental during difficult times. Instead, the specialization in the service sector does not result so risky, as this sector is by nature more flexible and able to renew itself more readily.

Martin and Sunley [91], on the other hand, do not draw conclusions by contrasting the manufacturing and service sectors, but suggest, again with a view to improved resilience, to focus the specialisation of the regions' economy on the technology- and knowledge-driven sectors, including high-tech manufacturing and knowledge-intensive services. The underlying idea is that these sectors possess key elements to create highly adaptable regional economic structures due to their innovation and transformation orientation.

Moreover, both in [35] and in [49] the role of the **industrial districts** is examined, places where firms whose core business is the same or highly complementary are highly concentrated nearby. Faggian et al., in particular, showed that being part of an industrial district in two of Italy's most traditional sectors, food and textiles, during the 2008 economic crisis, was a relevant and useful element in combating the recession.

Trade Dynamics

In today's interconnected global economy, the analysis of trade dynamics, which includes both **import and export activities**, has become increasingly used by different authors for comprehending the response of trade flows to external shocks and market fluctuations. As countries and regions navigate the complexities of international trade, understanding trade dynamics is key to decoding the mechanisms through which economies interact, evolve, and strive for stability in an ever-changing economic landscape.

This area is employed in approximately 27% of the papers focusing on economic shocks, but interestingly, it does not feature in any of the papers discussing natural disasters. This observation suggests that while trade dynamics might significantly influence the regional economy in terms of growth, employment, and overall prosperity, they may not directly play a substantial role in shaping the impacts and responses to natural disasters, at least based on the existing literature.

The authors primarily concentrate on trade dynamics that cross regional or national borders, rather than focusing on internal trade dynamics. For instance, [78] explore both export and import activities, while [35, 36] study external trade dynamics and export propensity using

indicators like EXPY (weighing the export basket by the implied productivity of each traded good) and MADEINITALY (representing traditional "Made in Italy" activities in 17 product categories, such as machinery and mechanics).

Duschl [42], on the other hand, examines export orientation by considering the share of a region's manufacturing activities in the national total as a proxy. Additionally, Mazzola and Simmie [95, 117] consider foreign direct investments (FDI) and their impact on regional economic development and resilience. While Simmie highlights their significance as a source of knowledge contributing to regional resilience, Mazzola also notes their potential negative effects on local relationships among firms. Moreover, Mazzola et al. explore the net foreign demand of a region, which indicates the region's ability to generate and sustain positive trade balances. A positive net foreign demand suggests a competitive advantage in exporting goods and services, while a negative net foreign demand may pose challenges to the region's economic resilience due to higher dependence on imports. They also analyze the impact of infrastructure, such as roads, airports, and maritime facilities, on export growth, identifying airports as having a significant impact in certain cases.

Finally, Tsiapa and Batsiolas emphasize trade as one of the five axes determining business resilience in Eastern European regions. According to their findings, exporters are less likely to experience credit rationing, as their international activity helps balance the risk of default brought on by domestic and foreign competition [122]. Additionally, foreign-owned companies are less dependent on bank credit, reducing the pressure of financial constraints during an economic crisis.

2.5.2. Infrastructure

The assessment of a region's **Infrastructure** system is articulated into three distinct categories:

1. Connectivity & access to communication networks;
2. Access to energy infrastructure;
3. Access to transportation network.

Connectivity & Access to Digital Network

The **Connectivity & Access to Communication Networks** area aims to evaluate regions' capacity to provide their residents with infrastructures for remote access to information and communication services. This encompasses both internet and telephone network access, despite being distinct infrastructures, as they share common analytical purposes.
While older studies used telephone network access as a measure of communication and information availability, especially in relation to timely disaster updates, recent research no longer relies

on this indicator. Telephone coverage has become widely accessible across many geographical contexts, except in less developed regions. However, disparities in digital connectivity persist, and the **digital divide** remains a reality.
In current literature, internet coverage is measured for similar purposes as telephone coverage once was. Therefore, to facilitate comparative analysis, a single area is considered to address the accessibility to connectivity and communication services in different regions.

This area holds greater relevance in studies focusing on resilience to natural disasters, primarily because communication networks play a critical role in facilitating information transmission, resource coordination, and emergency response during such situations. For instance, Koren et al. conducted a comprehensive assessment of urban systems' resilience in the face of natural disasters and utilized the availability of communication networks as an indicator to convey the idea of the possibility of sharing information about the disaster itself [84].
This area of indicators also complements the insights provided by other areas such as Digital opportunities and Digital skills. For example, [10] adopts an indicator on ultra-wideband coverage, which is fundamental for establishing adequate connections. This decision is driven by the recognition of the importance of addressing communication infrastructure gaps to enable smaller centres to seize post-COVID-19 pandemic opportunities, such as the rise of remote work and distant learning. These opportunities have the potential to foster economic development in these areas, but their realization hinges on having the appropriate connection networks in place.

Access to Energy Infrastructure

Access to energy infrastructure refers to regions' availability of energy and electricity, as critical sources for powering essential services and ensuring their uninterrupted operations during crises and natural disasters. As well as the Connectivity & access to the digital network area, the use of this area is restricted exclusively to papers on environmental disasters. In the broader context of the entire literature analyzed, it appears to have relatively lower relevance.

Nonetheless, some studies, such as [88] and [65], emphasize the immense significance of having access to energy and electricity in various aspects of modern life. During times of crisis, the availability of energy becomes a lifeline, enabling the delivery of life-saving medical treatments, facilitating coordination among response teams, and facilitating the distribution of critical information to affected populations. Beyond emergencies, electricity fuels homes, businesses, and industries, driving economic productivity and improving well-being.
Infrastructure investments, as highlighted by [48], are often proportional to opportunities, connectivity, and access to information in underserved areas. Moreover, the use of clean and sustainable energy sources can positively impact resilience by minimizing environmental effects and fostering energy security. In this sense, the area of *Access to energy infrastructure* may intersect with the ecological dimension of resilience in certain contexts.

Access to Transportation Network

The literature predominantly adopts the **Access to transportation network** area as the most frequently used within the Infrastructure macro-area. This underscores the critical role of transportation infrastructure in facilitating economic activities and enhancing the resilience of regions to both economic shocks and natural disasters.

Some studies emphasize the importance of efficient transport networks in supporting economic activities during normal times. For a more detailed analysis of regional accessibility to the transport network, [10] utilizes the "accessibility to urban and logistical nodes index." This index evaluates travel time to urban and logistical nodes in terms of the province average in minutes. The study derives this index from meticulous analyses of travel times from the centroid of each town to the three closest infrastructures, including ports, airports, railway stations, and highway toll stations. In a similar vein, [59] and [54] examine the regions' multimodal accessibility, using an index that captures the combined impact of three transport modes: transportation by train, road, and air.
Additionally, [105] and [74] use the population-weighted arithmetic mean of travel as a measure of local accessibility. This approach considers the spatial distribution of the population, recognizing that areas with a higher concentration of population typically have a higher demand for transport and play a more significant role in regional economic activities. The arithmetically averaged travel time incorporates factors such as distance, transport mode, and traffic conditions between various locations within the region.

Other studies explore the economic aspect of transportation networks. For instance, [39] delves into transportation costs, while [49] focuses on infrastructure investments in the transportation sector. Alternatively, [31] examines the percentage of the population owning a vehicle as a measure of individual access to the transport network.
Lastly, Hill et al. incorporate variables related to the age of the metropolitan area to gauge the correspondence between urban form and modern transport needs, as well as the structure and condition of urban infrastructure. Older regions are presumed to have less effective and efficient infrastructure, making them more susceptible to failures and maintenance demands, and thus less resilient [73].

2.5.3. Institutions

The third and final aspect of the economic dimension is represented by the role of **institutions**. This macro-area is further divided into three distinct areas:

1. Governance arrangements;
2. Financial conditions;
3. Safety.

Governance Arrangements

The **Governance arrangements** area pertains to how institutions are structured to guide and manage the dynamics of a region, and subsequently, how the region is administered and held accountable for achieving strategic and operational objectives. Governance encompasses the distribution and regulation of power, which shapes and governs the implementation and outcomes of local initiatives. It involves the systems, procedures, and connections that govern decision-making processes, allocate authority, and delegate responsibilities.

The diverse elements encompassed within this area justify its relatively high importance in the literature. Particularly, it is considered in half of the papers focusing on natural disasters. One of the key factors influencing the response to natural disasters is the preparedness and efficiency of response plans tailored to the specific location and challenges. For instance, in [25], Chan et al. examined the presence of disaster prevention plans, highlighting the focus and effectiveness of the region's risk management and emergency preparedness policies. Similarly, [88] incorporated in their analysis the government's responsibility for development planning, anticipating potential disasters, and the existence of regulations related to disaster preparedness.

An extensively explored factor within this area is the **institutional structure**, which holds crucial significance as institutions establish the rules, mechanisms, and processes guiding interactions between different economic and social actors within a region. The expectation is that cities with a flexible and responsive institutional structure are better equipped to prevent crises and respond more swiftly to emergency situations. For instance, Balland et al. in [13] considered the inverse of the non-competition enforcement index developed by Garmaise [57] for U.S. states to account for institutional flexibility. Non-competition agreements are contracts that legally prohibit employees from joining a rival company or establishing a spin-off, potentially hindering the free flow of information and labour within regions.

Boschma extended the analysis of institutional structure by incorporating key institutional agents in [15]. These actors hold prominence in the institutional context of a specific sector or domain and are often responsible for formulating and implementing policies, norms, and strategies that may influence the resilience of a system.

Contractual flexibility in the public sector [35] and labour market [73] were addressed by other authors in the context of their impact on regional economic resilience. Contractual flexibility refers to the capacity to update and adjust contractual agreements to adapt to changing conditions, while labour market flexibility is assessed with a variable for whether the region is wholly or predominantly in a state that has a right-to-work law. The absence of mandatory union representation may weaken collective bargaining power and worker rights, potentially leading to lower wages, reduced benefits, and less job security.

Additionally, several studies such as [44, 47, 84, 122] have examined the importance of the quality of government and the political environment in regions. For example, [44] assessed the

Good Governance Index, a measurement tool that quantifies and compares the effectiveness of governance in different areas by evaluating various aspects of governance, including political, economic, administrative, and social factors.

Financial Conditions

The **Financial conditions** area explores which are the dynamics and rules that govern and influence the economy of a region. It includes an overview of the region's financial structure and an understanding of how it is perceived in terms of stability and reliability by other regions and internal actors. In contrast to the Financial solidity area previously discussed in Section 2.5.1, this area evaluates how the authorities responsible for governing the region are managing the overall finances rather than focusing on the management of money and financial resources within specific organizations. Contrary to what might be expected, this area is used more often in studies of resilience to natural disasters than in studies of economic shocks, but there is no lack of applications in the latter.

[17] delved into the importance of various factors such as banking industries, control of interest rates, credit markets, external debt, fiscal deficit, and inflation, which collectively contribute to the financial condition of a region. On the other hand, [22] highlights the significance of internal and external credits, insurance and reinsurance payments, reserve funds for disaster management, and the margin available for budgetary reallocations and new taxes, arguing that these indicators reflect the region's capacity to effectively handle financial shocks and allocate resources.

In [25], two critical aspects are emphasized: resource distribution capability and the government's financial capability. The former refers to the ability of a region to allocate resources efficiently during crises, while the latter assesses the financial strength and capacity of the government to support economic recovery and resilience-building efforts. These indicators provide insights into the financial preparedness and stability of a region.

In [31] the main target is municipal revenues as understanding the revenue streams available to local governments helps assess their ability to provide necessary services and support during times of crisis. [32] considers financial conditions by looking at disaster mitigation, flood coverage, and municipal services. By examining the percentage of the population covered by hazard mitigation plans, the percentage of housing units covered by National Flood Insurance Program (NFIP) policies, and the allocation of municipal expenditures for fire, police, and emergency medical services (EMS), these authors shed light on the financial resources allocated to disaster management and response.

In [65] the focus is on bank deposits as they contribute to a region's resilience by facilitating access to capital and supporting economic activities during challenging times. Similarly, Lessy et al. highlighted in [88] the presence of financial institutions as an essential measure.

[92] took a broader perspective, considering factors such as the national financial environment (including interest rates and other macroeconomic indicators), loan conditions, equity market conditions, alternative sources of finance (both loans and equity), and the support provided by local governments in terms of financial assistance.

Furthermore, [95] guided the attention on provincial investments in project financing as a ratio of the total fixed investment in the province. This indicator reflects the commitment of local authorities to finance and support infrastructure development, which contributes to economic resilience and evolution.

Additional studies highlight specific financial indicators, such as corporate tax revenues/1000 ([116]). Similar indicators provide insights into the fiscal health of regions, the tax base, and the affordability of living and doing business in a particular area, all of which can offer details on particular development fields. In particular, corporate taxation per capita "can be used as an indicator to gauge the level of community revenue available for public benefit that is above and beyond other forms of taxation" [116]. A greater per capita tax, indeed, suggests a large community's corporate tax base and indicates that there are businesses and industries in the area to meet demands for employment and growth. Alternatively, it may reveal whether a location is prone or not to offer tax incentives.

Safety

Safety refers to the presence of preventive infrastructures or facilities to anticipate or limit dangers and to appropriately respond to their consequences, reducing their negative impact and minimising the area actually affected. The concept of safety has gained prominence relatively recently as societies recognize the imperative to develop comprehensive strategies for addressing the escalating frequency and severity of disasters. It is never considered in studies on economic recessions, instead, it is used in at least half of the studies on environmental disasters, as would be expected.

To investigate the resilience of communities in the face of natural disasters, a study conducted by Cutter et al. in 2008 included an analysis of emergency services and emergency response plans [31]. In addition, a measure of infrastructure resilience was considered, namely the state of residential buildings. In another study conducted two years later, a similar approach was taken, focusing on the potential for access/evacuation through the principle arterial miles per square mile and the housing age [32].

Chan et al. in their study of disaster resilience in the Tan-sui river basin focus on *rescue capability*, which refers to the capacity and effectiveness of emergency response and disaster relief operations [25]. The same idea is expanded in [84], to include, other than the quality of emergency services, the quality of healthcare services. Finally, in [88] a set of very specific proxies is used, including the condition of residential buildings, their geographic location (on

the coast or in the hills), the existence of early warning systems, coastal protection facilities, the availability of shelters and strategic reserves, and the presence of trained disaster response teams.

2.6. The Environmental Dimension

The **environmental** one represents the last dimension identified in this research. It focuses on various aspects of the natural environment that significantly impact the health and safety of the resident population, ultimately influencing the region's attractiveness and resilience. Given the ongoing climate crisis, these environmental factors play an increasingly crucial role in people's quality of life.

From Table 2.1, it becomes evident that the environmental dimension holds the least relevance within this literature review. The distinctive Table 2.4, comparable to those presented for the social and the economic dimensions, shows the relevance by each area. While it is frequently considered in studies of resilience to natural disasters, it is consistently excluded from the literature on economic recessions, where environmental aspects are considered of little or secondary importance, and mostly seen as a consequence of other underlying issues. An exception to this pattern is found in [116], where the author, although focusing on a natural disaster (Hurricane Katrina), delves only into its social and economic impact to capture the regional community resilience of Mississippi. Similarly, in [32], while establishing proxies of ecological systems' resilience to various natural disasters, the ecological dimension was deliberately excluded due to data inconsistency and applicability concerns.

MACRO-AREAS	AREAS	Relevance	Relevance in economic shocks	Relevance in natural disasters
Pollution	*Air pollution*	*8%*	*0%*	*33%*
	Water pollution	*6%*	*0%*	*33%*
Natural hazards	*Sismic risk*	*6%*	*0%*	*17%*
	Hydrogeological risk	*6%*	*0%*	*17%*
Natural resources	*Soil condition*	*14%*	*0%*	*67%*
	Nature capital	*8%*	*0%*	*50%*
Waste	*Waste sorting*	*8%*	*0%*	*33%*

Table 2.4: Percentage incidence of areas in the literature of the environmental dimension of regional economic resilience.

In response to the urgency of addressing climate-related factors, the environmental dimension gained greater relevance in the study of the COVID-19 pandemic. The Pandemic highlighted the impact of regions' resistance to climate change consequences and its influence on their attractiveness and vitality. As a result, the significance of long-term sustainability and the critical role of the environment in the transmission of infectious diseases were emphasized.

2.6.1. Pollution

The first macro-area to be considered is **Pollution**, measured through two main areas, namely *Air Pollution* and *Water Pollution*, which are the most severely impacted.

Air Pollution

Air pollution refers to the presence of hazardous chemicals or compounds in the air in amounts that reduce drastically its integrity, harming people's quality of life and endangering their health. Since pollutants released into the air have the potential to exacerbate the damage caused by climate change, and given the current urgency to address the climate crisis, air pollution is considered by Rizzi et al. as a **vulnerability exacerbator** [110]. Indeed, it can increase health costs, reduce productivity and damage valuable assets, leading to far-reaching negative economic consequences that must be considered in resilience planning to preserve the long-term viability of the ecosystem. Moreover, as [10] points out, European Union directives have set the goal of reducing greenhouse gas emissions by at least 55% compared to 1990 levels by 2030 and achieving climate neutrality by 2050. This shapes the conditions under which a region is competitive and attractive and has binding implications on the amount of money to be invested by each of them to tackle pollution reduction. Taking this into account, Azzone et al. identify the number of days on which the 50 $\mu g/m^3$ PM10 threshold was exceeded (ISTAT, 2018) as the most suitable proxy to be used to account for air pollution [10].

Water Pollution

Water pollution describes the occurrence of dangerous substances in water that compromise its safety and make it poisonous to both humans and the environment. Given the critical importance of the availability of dependable clean water for human existence and socioeconomic growth, [110] decided to take this aspect into account while analyzing regional resilience.

In fact, tainted water sources can result in a number of issues: in addition to harming the fishing and tourist businesses, water shortage is directly related to agricultural losses and it consequently lowers regional output. Regions may lessen these effects or at least take preventative measures by taking water pollution into account when designing their resilience plan.

2.6.2. Natural Hazard

Looking at the **Natural hazard** macro-area, the focus is in particular on the *Seismic* and the *Hydrogeological risk*.

Seismic & Hydrogeological Risk

Seismic risk assesses the probability of an earthquake occurring in a given geographical area and allows for the forecasting of the resulting negative consequences for people, structures and the environment. On the other hand, **Hydrogeological risk** refers to the evaluation of potential threats and vulnerabilities associated with water-related activities and geological conditions in a specific territorial unit. They are both considered by [10] with the objective of including in the analysis both the territory's ability to withstand climatic disasters and the security of its resident population. Indeed, they are both crucial in determining the safety of a given area and they thus play a key and guiding role when dealing with disaster management and planning.

Differently, in [25] the focus is limited to hydrogeological risk and deepens its potential danger by looking at water resource conservation and river basin management. This provides a more specific view of the subject but at the expense of losing a holistic approach to recognising the interconnectedness of geological, hydrological and social factors in determining overall risk levels.

2.6.3. Natural Resources

Within the macro-area of **Natural resources**, two site-specific aspects have been included, namely the *Soil condition* and the *Nature capital*.

Soil Condition

Soil condition denotes here all the variables that affect and determine the particular land state of a given region, as well as any alterations brought on by natural or human sources. It proves to be the most relevant area of the environmental dimension of resilience since the survival of the earth's biological inhabitants depends heavily on the soil. Indeed, not only it provides the basic resources needed for human life on Earth, but it also fosters economic and social advancement. This resource is regarded as scarce because of its lengthy generation period. Therefore, it's critical to control its condition in order to safeguard the ecosystem and the living things that reside there.

While most papers focus on soil conditions in terms of quality or contamination [31, 84, 88, 110], in [10, 25] the interest is on soil structure and in understanding how it has been utilized by humans. In particular, in [10] it is considered the soil consumption, which allows for an analysis of land evolution with a focus on lost or threatened natural functions. More precisely, soil

consumption is defined by ISPRA[1] as "the phenomenon associated with the loss of a fundamental environmental resource, due to the occupation of an originally agricultural, natural or semi-natural surface. The phenomenon, therefore, refers to an increase in the artificial cover of land, linked to settlement dynamics". The indicator used to express it is the percentage of artificial land cover.

Nature Capital

Nature capital refers to a territory's unique combination of traits and resources that set it apart from others or provide unique and noteworthy situations, both in a positive and negative sense. This area refers to factors significantly impacting the region's ability to recover in the face of a shock. In order to express this, [25, 31, 124] use biodiversity, which expresses the number, variety and variability of living organisms and how they vary from one environment to another over time, thus expressing the richness of the region and its potential. Conversely, in [25], the presence of environmentally sensitive areas is analysed, namely particularly susceptible or vulnerable geographical areas where the presence of human activities or natural events can cause significant damage, thus highlighting a particular fragility of the region. Lessy et al., in their study on Maitara Island in northern Indonesia in 2018, assessed the resilience of communities to natural disasters and climate change by considering the trend and condition of mangrove vegetation and the types of natural resources cultivated [88]. Lastly, the ecosystem services value index and the human-value index of ecosystem services are used in [44], which relatively represent the positive benefits that wildlife or ecosystems provide in general and to humans.

2.6.4. Waste

Considering the **Waste** macro-area, attention was paid in particular to *Waste Sorting*.

Waste Sorting

Waste sorting refers to whether or not a particular region adopts a centralised waste separation process by which waste is ordered into categories, based on material or recyclability, and then treated and used differently accordingly. Indicators belonging to this area ad utilized by Dallara and Rizzi in 2012 in [33] and taken up again in 2018 in [110]. Also [10], considers waste sorting to evaluate "the community's attention and sensitivity to environmental issues". Particularly, the volume of the separate municipal solid waste collection might be used as a gauge of a region's ability to reduce its use of resources, waste production, and emissions compared to others' areas under comparable circumstances. It is among the least assessed areas in the resilience literature, even disappearing in the case of studies on dealing with resilience to shocks of an economic nature.

[1] Istituto Superiore per la Protezione e la Ricerca Ambientale

3 | Research Design & Model Development

This chapter is intended to introduce the conceptual framework upon which the **research design** investigations will rely and a specific focus on the **model's construction**.

A combination of quantitative and qualitative research approaches is adopted to provide a comprehensive understanding of the research problem. Both directions offer distinct advantages that, when combined, can yield more robust and nuanced findings, enhancing the overall quality of the research.

The **quantitative approach** focuses on the semi-systematic collection and analysis of numerical data to identify trends, patterns and relationships among variables of interest. This method is particularly valuable for establishing correlations, determining the prevalence of specific phenomena and generalizing results to a larger population. **Statistical analysis** was the employed technique in this quantitative research part.

The **qualitative approach**, on the other hand, completes this overview and allows for rationalization. It involves the collection and analysis of non-numerical data, such as theories, findings and textual analysis from past research on the topic but also, according to a much wider perspective, analysing several factors more or less related to the topic. This approach is particularly valuable for exploring complex and detailed aspects of the research problem, providing in-depth insights to start and drawing edges of such a broad concept as resilience.

The above-described **mixed approach research design** allows for triangulation, where findings from one approach can be corroborated or complemented by the other, enhancing the overall validity and reliability of the research outcomes. Additionally, the integration of these approaches can lead to a more holistic and enriched interpretation of the research findings, offering a more complete picture of the research problem.

Overall, the decision to employ a combination of quantitative and qualitative research approaches is driven by the desire to capture both the **breadth** and **depth** of the research topic. By doing so, the study aims to produce valuable insights that can inform theory, practice, and policy related to the subject matter under investigation.

To clarify the structure of the research methodology, a **flowchart** has been created, as illustrated in Figure 3.1. This flowchart outlines the various stages of the procedure, emphasizing the *inputs*, *processes*, *decision nodes*, and *outputs*, up to the "Data Collection" phase. The intricacies of the latter will be addressed in detail in Chapter 4.

To address the research inquiries introduced in Section 1.3, the development of an adaptable approach for measuring regional economic resilience in the short term assumes paramount significance. With the establishment of the fundamental dimensions of analysis of resilience–namely, resilience *to what*, *of what*, and *over what period*–it is possible to proceed with the construction of the **measurement model**.

The primary objective of the model is to "explain" the features of resilience, as reflected in a dependent variable. This explanation is achieved by mathematically integrating a range of indicators associated with the resilience dimensions identified in the existing literature. The model's construction involves the initial definition of **dependent variables** representing short-term resilience itself and subsequent identification of an array of **independent variables** for investigation. These independent variables elucidate their potential to influence the diverse resilience levels exhibited by different regions. In essence, these indicators are incorporated as *predictors* of resilience indices due to their perceived capacity to influence said indices.

Given these considerations, the flow of the research methodology is divided into two main branches:

- the first relating to the definition of the **dependent variables** of the model, concerning synthetic measures of resilience;
- the second relating to the selection and definition of the **independent variables** to be included, which constitute a short-term resilience driver dashboard.

Both branches start from an output of the literature review process: on the one hand, the synthetic measures of resilience and, on the other hand, the categorization in dimensions, macro-areas and areas of resilience.

The following sections are intended to elucidate the stages of each of the two branches of the flow.

3.1. Definition of Resilience Synthetic Measures

In line with the comprehensive definition of regional economic resilience in this thesis, the chosen approach to modelling resilience is the **Martin's Framework**, extensively deliberated upon in Section 1.1.2. The four phases of resilience – Resistance, Recovery, Re-orientation, and Renewal – are all pertinent for measuring resilience across its entirety. However, it is pertinent to note

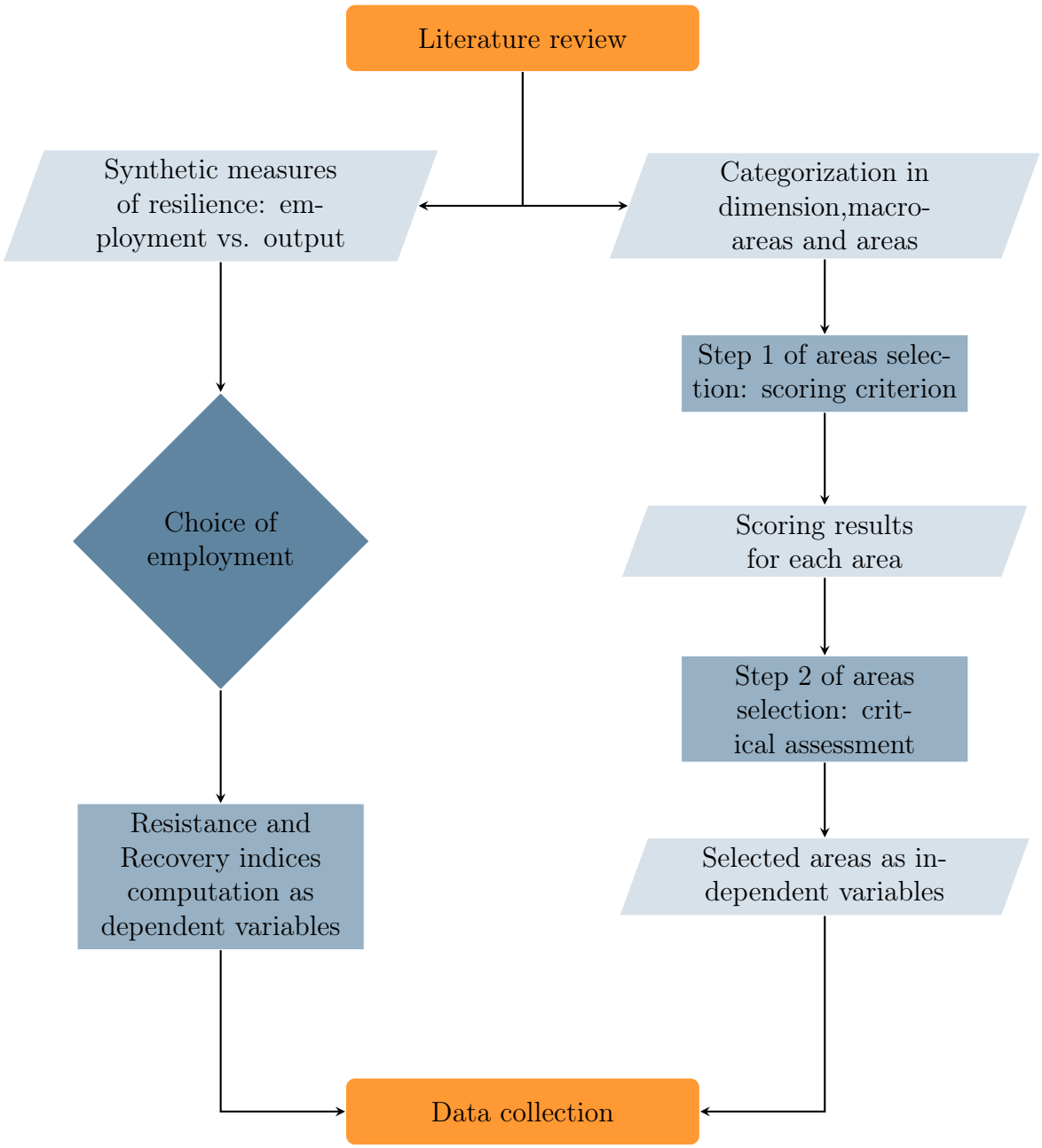

Figure 3.1: Research methodology flowchart.

that the latter two dimensions pertain to medium- and long-term resilience, while the initial two predominantly address short-term phases.

Consequently, given the **temporal constraints** associated with evaluating Italy's response to the COVID-19 Pandemic and the already explained relevance of short-term analysis, this study will focus exclusively on the **Resistance** and **Recovery** phases. Each of these phases will be modelled as a dependent variable in separate but specular models. Thus, the model's application and analysis will be replicated for both these resilience phases.

The forthcoming sections will delve into the intricacies of calculating the Resistance and Recovery dimensions, exploring the methodologies and strategies employed to quantify these aspects.

In order to construct a Resistance index and a Recovery index, it is essential to identify a phenomenon for observation that reflects the overall economic response of the examined region to the shock. Extensive literature exploration has underscored the prominence of the **employment rate** and **output rates** (e.g., GDP) as key explanatory factors for gauging regional economic resilience in a synthetic manner. The decision between these two paths for constructing the Resistance and Recovery indices ultimately leans toward utilizing the **employment rate**, aligning with the specific focus of this study.

3.1.1. Choice of Employment

The rationale behind favouring **employment rate** over GDP as the variable to use to build the Resistance and the Recovery indices, is related to both theoretical and practical reasonings.

For instance, employment tends to return to pre-shock levels with a longer lag compared to GDP [86]. Indeed, it was discovered in the wake of severe past and present economic crises that, while the cycle of output from peak to trough lasts around 1.9 years, that of unemployment accounts for a historical average of 4.8 years [59].
In addition, labour market data are typically more **accessible** and **trustworthy** at lower geographical scales, such as the regional, provincial or municipal level [66]. Since the labour market is one of the primary levers used by firms when they need to cut costs during a crisis, the impact of a shock may be especially pronounced in these markets [52, 82] and thus important to be analyzed.
Furthermore, using employment rather than GDP addresses another important aspect. It takes into account the possibility that a highly innovative economy may experience a reduction in the workforce while still showing an overall increase in GDP. If such a situation occurs in response to an economic shock, critics could argue that the economy did not demonstrate resilience to the crisis due to its poor employment performance. By focusing on employment as a resilience measure, this potential outcome is mitigated, as innovation does not typically result in increased employment alongside declining GDP levels [18].

To conclude, the vitality of the labour market, understood as the change in employment, seems to reflect the social, and not only the economic, impact of shocks better than output measures. Indeed, a decline in employment rates may also translate into a worsening of other factors of the social dimension of a regional reality, e.g. it may lead to imbalances, generate major inequalities and social tensions [86]. Therefore, through this choice, a more comprehensive measure is available that somehow intersects several dimensions of resilience itself at the same time.

3.1.2. Resistance Computation

Resistance, as previously described, refers to the sensitivity of an economic region to disruptions and its capacity to withstand and recover from adverse impacts. To quantitatively assess it, the **Sensitivity Index** *à la Martin* is employed as a reliable proxy. The Sensitivity Index (SI) is calculated by comparing the relative changes in employment levels between a specific province and the nation as a whole for two consecutive years ($t_1 = 2020$ and $t_0 = 2019$).

$$\text{SI} = \frac{\Delta E_p(t_1, t_0)}{\Delta E_n(t_1, t_0)}$$

Where:

- $\Delta E(t_1, t_0) = \frac{E(t_1) - E(t_0)}{E(t_0)}$ represents the change in employment level between two time periods, specifically between year t_1 (2020, during the shock) and the previous year t_0 (2019, pre-shock);
- $E_p(t_0)$ refers to the employment level in the province being analyzed at time t_0;
- $E_n(t_0)$ signifies the employment level at the national level at time t_0.

This index serves as a measure of the province's resistance in terms of employment dynamics to COVID-19 disruptions, considering how its employment changes compare to the corresponding national-level changes during the same period. It provides an objective measure of the extent to which the specific province was able to cope with the Pandemic right at the beginning of its course.

Index values above 1 indicate low resistance, implying that the region experienced a more significant decline in employment compared to the national average, making it more sensitive to the shocks and disruptions that ensued. On the other hand, values below 1 suggest high resistance, indicating that the region demonstrated greater stability in its employment levels compared to the national average, and therefore exhibited a higher capacity to withstand the economic impacts of the Pandemic.

Results are provided in Table A.3 in Appendix A.

3.1.3. Recovery Computation

Moving to the **Recovery** analysis, the focus revolves around the assessment of the speed and extent of provinces' capacity to restore previous performance and economic functioning. This aspect is measured by looking at the different provinces' speed to rebound and restore to the pre-shock level of employment (at $t_0 = 2019$).

To capture the trajectory of recovery, the employment level delta was computed for each province during the post-shock years, particularly examining the deltas for 2021-2019 and 2022-2019. The Recovery Index was subsequently derived by averaging the two computed results in the following manner:

$$\text{RI} = \frac{RI_{2021} + RI_{2022}}{2}$$

Where:

- RI_{2021} represents the recovery achieved in 2021, calculated as the difference between the employment level delta for 2021-2019 and the employment level delta for 2020-2019. In formula:

  $$\text{RI}_{2021} = \Delta E(t_2, t_0) - \Delta E(t_1, t_0) = \frac{E(t_2) - E(t_0)}{E(t_0)} - \frac{E(t_1) - E(t_0)}{E(t_0)}$$

  This subtraction accounts for a normalization of the change in the employment level that accounts for the magnitude of the shock experienced.

- RI_{2022} represents the recovery attained in 2022, calculated as the difference between the employment level delta for 2022-2019 and the previously calculated recovery for 2021. In formula:

  $$\text{RI}_{2022} = \Delta E(t_3, t_0) - \text{RI}_{2021} = \frac{E(t_3) - E(t_0)}{E(t_0)} - \text{RI}_{2021}$$

In this process, provinces with positive values indicate a certain level of recovery capacity; the magnitude of the score correlates with the extent of this recovery capacity. Conversely, negative values denote a deficiency in recovery capacity. The Recovery Index thus encapsulates the provincial capacity to recuperate from the shock, factoring in the shock's severity to provide a more comprehensive assessment.

To enhance the interpretability of the results, a subsequent step involved performing min-max normalization on the calculated Recovery Index values. This normalization process scales the Recovery Index values between 0 and 1, where 1 represents the maximum recovery capacity observed and 0 corresponds to the minimum recovery capacity. Additionally, this normalization approach introduces a degree of weighting to account for the response of other provinces. As

a result, the normalized Recovery Index values offer a clearer and standardized representation of the provinces' recovery capacities, facilitating a more intuitive understanding of the analysis outcomes.

Results are provided in Table A.3 in Appendix A.

3.2. Definition of the Recovery & Resistance Determinants Dashboard

In the existing literature on regional economic resilience, numerous areas of indicators have been identified and discussed, as outlined in Chapter 2. To construct a comprehensive but concise measurement method, it is crucial to carefully select the relevant areas and choose the most appropriate indicators.

The selection process is not a trivial task and can present complex challenges. In this thesis, a method comprising two distinct steps is employed. The first step involves a **scoring system-based areas selection method**, which takes into account several evaluation factors.

During implementation, each area is evaluated and assigned a score based on the assessment of each factor, ranging from 1 (poor) to 5 (excellent). These scores are then aggregated to obtain an overall score for each area. Areas with higher scores are considered the most suitable for inclusion in the dashboard during the initial selection phase.

No differential weights were assigned to the evaluation factors, as all factors were deemed equally relevant.

The proposed scoring method offers a simple, efficient, and structured approach. The objective is to develop a dashboard that encompasses all three dimensions of resilience: social, economic and environmental.

However, this approach may result in the selection of numerous areas for each dimension and does not involve in-depth case evaluations. For instance, the potential overlap between different measurement areas might not provide additional value if included in the same model. Hence, as the second step of the selection process, a **critical analysis** is conducted on the initially selected areas to provide further rationale for their inclusion.

3.2.1. First Step of Independent Variables Definition: Scoring Criterion

A thorough understanding and precise definition of the parameters used to evaluate the areas are of utmost importance.

The first parameter taken into account is the ***relevance*** of each area in the literature. This evaluation is based on the frequency with which the area is utilized in the analyzed studies. The relevance of an area in the literature is calculated as the percentage of studies that adopt that area, out of the total number of quantitative studies considered in the research. The frequent usage of an area in the literature signifies its widespread recognition and adoption by scholars in the field of regional economic resilience. Areas that demonstrate higher relevance in the literature are deemed more reliable and valid, thereby receiving a higher score.

Secondly, the ***applicability*** of the areas is assessed, referring to the breadth of their usage. One of the primary objectives of this thesis is to develop a robust measurement system for regional economic resilience that is adaptable and well-suited to analyze diverse types of shocks. In light of the COVID-19 pandemic's far-reaching impacts, which have manifested in various forms, affecting multiple facets of society, the economy, and the environment, an evaluation of resilience necessitates the consideration of a broad array of situations and phenomena. Therefore, the extent to which an area is applicable plays a pivotal role in the selection process. To calculate the score, the absolute difference in the relative frequencies of the area's usage in studies on resilience to natural disasters and in studies on economic shocks is considered. A higher absolute difference suggests a lower applicability of the area, indicating that it is more relevant and utilized in studies of one typology of shock compared to the other. The underlying assumption is that the category of papers adopting the area serves as a proxy for its effectiveness in representing a measure of resilience for the specific type of shock encountered. Areas demonstrating greater applicability will receive higher scores, as they provide a more holistic understanding of resilience. This, in turn, enables a more accurate assessment of the ability to adapt and recover from different types of shocks.

Subsequently, the ***quantifiability*** of areas is assessed, which pertains to their ability to be measured clearly and unambiguously. An effective area must rely on well-defined and easily accessible indicators. The clarity of measures used is crucial to ensure the reproducibility and comparability of results. This evaluation examines the clarity of measures employed in the literature when quantifying the area. Areas that can be quantifiably measured and aligned with the intended objective receive higher scores, as they offer greater practicality and enable a precise assessment of the phenomena under study. Conversely, areas that are ambiguously measured, with highly differentiated indicators, or challenging to interpret receive lower scores due to the potential difficulties in accurately capturing the relevant information.

The ***precision*** is another crucial factor considered in the described scoring method, representing the area's correlation with the COVID-19 pandemic and the current context of technological evolution and post-pandemic transformation. Essentially, it serves as an indicator of the area's "modernity". The analyzed literature includes studies of varying ages, which may either underestimate or overestimate the significance of certain areas in relation to the current context. Therefore, it is essential to assign greater scores to areas that are relevant to the nowadays

socio-technological context and the *new-normal* environment following the Pandemic. A precise area enables a deeper understanding of the challenges and opportunities for resilience in these times.

Lastly, the ***memory effect*** or *temporal persistence* of an area is considered as an evaluation parameter in the selection method. Areas that account for this effect are capable of reflecting the long-term impacts of a shock and subsequent changes. This enables the assessment of resilience within the context of enduring transformations and facilitates the identification of necessary strategies and actions for adaptation in an uncertain future. Areas with indicators exhibiting a more prolonged delay in restoring original levels, indicating more persistent impacts, receive higher scores. Conversely, areas with indicators that naturally return rapidly to pre-shock values without "memorizing" lasting changes receive lower scores, as they may lead to misleading or conflicting results depending on the considered time horizon.

Having defined the factors adopted for the scoring method, the allocation of individual scores to each area by parameter and overall scores follows in Table 3.1, Table 3.2 and Table 3.3.

The final **output** of the scoring criterion is considered to be the areas with an overall score above the average for each dimension - highlighted in green.

AREAS	Relevance	Applicability	Quantifiability	Precision	Memory effect	Overall score
Financial solidity	2	5	2	3	4	16
Entrepreneurship	2	3	3	4	3	15
Competitive profile	2	5	2	4	4	17
Innovation	3	5	4	4	3	19
Diversification vs. Specialization	4	4	4	4	4	20
Agglomeration economies	3	4	3	3	4	17
Trade dynamics	2	3	4	4	4	17
Connectivity & access to digital network	2	1	4	5	4	16
Access to energy network	1	4	3	3	3	14
Access to transportation network	2	2	5	4	4	17
Governance arrangements	2	2	2	5	3	14
Financial condition	2	2	4	5	4	17
Safety	2	1	3	5	2	13

Table 3.1: First step selection of areas of the economic dimension of resilience.

AREAS	Relevance	Applicability	Quantifiability	Precision	Memory effect	Overall score
Social fragility	3	1	4	5	5	18
Social cohesion	2	4	2	3	3	14
Social integration	2	3	3	3	4	15
Psychological factors	1	5	1	5	4	16
Health	2	1	3	5	4	15
Demographics	2	2	3	4	3	14
Population change	2	2	5	3	5	17
Social services	2	4	2	3	2	13
Health facilities	2	1	5	5	4	17
Digital opportunities	1	5	4	5	4	19
Competencies	3	2	3	4	5	17
Digital skills	1	5	2	5	4	17

Table 3.3: First step selection of areas of the social dimension of resilience.

AREAS	Relevance	Applicability	Quantifiability	Precision	Memory effect	Overall score
Air pollution	2	2	3	2	4	13
Water pollution	2	2	5	2	4	15
Seismic risk	2	4	5	2	3	16
Hydrogeological risk	2	4	5	2	3	16
Soil condition	2	1	4	4	5	16
Nature capital	2	1	1	2	3	9
Waste sorting	2	2	5	3	3	15

Table 3.2: First step selection of areas of the environmental dimension of resilience.

3.2.2. Second Step of Independent Variables definition: Critical Assessment

This second step takes as input the outcome of the scoring method, namely a panel of chosen areas in each dimension. The excessive number of areas in some dimensions posed practical challenges for their inclusion as independent variables in the final model. As a result, the second step of **critical assessment** was employed to further select the variables of interest, prioritizing those that contribute to a comprehensive and in-depth understanding of resilience

across its social, economic, and environmental dimensions.

This step leverages the **qualitative approach** previously mentioned in order to delve into the interpretations and underlying reasons for the selection of resilience areas of indicators. It draws upon a diverse range of data sources: the **interdisciplinary nature** of the explored subjects demanded the integration of heterogeneous sources, spanning disciplines such as economics, sociology, macroeconomics, business theories, and strategy. Within this context, the incorporation of qualitative data from various research studies, analyses, and scientific publications enabled a thorough and contextualized examination of the themes.

The critical assessment involved a closer examination of each area, taking into account factors such as **conceptual coherence**, **suitability** for the research objectives, and **representativeness** of the phenomena analyzed.

The integration of the structured scoring method with critical assessments was implemented to enhance the usefulness and relevance of the areas selected while maintaining a rigorous methodological foundation. This combined approach overcomes the limitations associated with relying solely on the scoring method, allowing for a final selection of areas that effectively address the specific research objectives.

The **output** of the second step of the independent variables definition is schematized in Table 3.4, showing the **selected areas** and respective indicators/proxies chosen to best express their contribution.

In the ensuing paragraphs, the justification for the selection of this second step, organized into sections for each of the designated areas, will be examined.

Within the **social dimension** of resilience, the process led to the selection of the following areas:

- Social fragility;
- Population change;
- Health facilities;
- Digital opportunities;
- Competencies.

Social Fragility

The selection of the **social fragility** area is justified by its significant role in responding to unexpected events and various types of shocks. For instance, in the case of natural disasters, individuals living in marginalized areas or with limited resources are particularly vulnerable.

Dimension	Macro-area	Area	Indicator/proxy
SOCIAL	Community well-being	Social fragility	Structural dependency ratio
	Community composition & development	Population change	Internal migration rate
	Service availability	Health facilities	Hospital emigration
		Digital opportunities	Propensity to remote work
	Human capital	Competencies	Education level
ENVIRONMENTAL	Natural hazards	Seismic risk	Seismic risk
	Natural resources	Soil condition	Land consumption
	Waste	Waste sorting	Waste sorting diffusion
ECONOMIC	Firms	Innovation	Patent intensity
		Diversification	Relative diversity index
		Agglomeration economies	Urbanization degree
	Infrastructures	Connectivity & access to digital network	Ultra-broadband penetration
		Access to transportation network	Public transport speed
	Institutions	Financial condition	Administrative budget balance

Table 3.4: Second step selection of areas and respective indicators.

Similarly, an economic crisis disproportionately affects people in precarious economic and social situations, who may lack essential resources and face difficulties accessing basic services. The repercussions of an economic crisis can be so severe for these individuals that they become dependent on external assistance, making it challenging to rebuild their lives afterwards.

Social fragility **amplifies the negative impacts** of shocks, rendering individuals and communities more vulnerable. This was evident during the **COVID-19 pandemic**, which exacerbated existing inequalities and disproportionately affected different regions.

Several factors contribute to this disparity. Social fragility influenced people's adherence to restrictions and lockdown measures, with financially stable individuals better equipped to adapt to changing circumstances. Regions with fragile health systems and inadequate infrastructure faced

greater challenges in managing the Pandemic effectively. People in socially fragile situations, including precarious workers, migrants, refugees, and the homeless, bore a heavier burden.

Government responses to the Pandemic also reflected variations in social protection networks. Countries with robust social protection systems and financial resources could provide economic support to citizens, such as emergency payments and unemployment benefits; while those with weaker systems struggled to adequately assist the most vulnerable. A certain **regional disparity** was also highlighted: some regions demonstrated a greater capacity to react and to offer adequate support to citizens, absent in other realities.

The assessment of social fragility is vital because a region's ability to protect its most vulnerable residents during a shock determines its level of resilience. It provides insights into the socioeconomic dynamics of regions and highlights areas that require targeted actions to reduce inequality and enhance adaptability. By promoting fairness and inclusivity, such an assessment can assist policymakers in strengthening support networks, developing social inclusion policies, and implementing targeted programs to address vulnerabilities.

In particular, social fragility is analyzed here by looking at the **Structural Dependency Index**, which measures the reliance of a region's population on its working-age group. A higher percentage of non-working-age individuals relative to the working-age population indicates a potentially vulnerable social structure, as it may strain the workforce's ability to support dependents and could impact social welfare systems.

Population Change

The area of **population change** is regarded as significant, as it has profound implications for the **human capital** within a region and gives rise to various accompanying effects.

Emigration to more appealing regions leads to the outflow of human capital, whereas the ability to attract immigration flows of the workforce presents an opportunity to address employment gaps and enhance regional productivity.

In many cases, the negative natural population balances have been compensated through migration, which has benefited regional growth. Therefore, immigration in Italy, as in other European countries, generates an overall "balance" at the national level that results in a positive cost-benefit ratio. However, the mobility of people and economic activities also affects Italy in terms of **internal movements**, due to the different attractiveness of each area and, in turn, influence it [10].

That is, usually individuals with the highest levels of skills and education are the most geographically mobile. This is the recurring theme of the **brain drain**, which not only concerns Italians migrating abroad but also the movement of Italian students and workers between regions. In particular, skilled and educated people are moving from the regions of southern Italy to those

of northern Italy, thereby depriving the southern regions of more productive human capital.

More generally, the increase in mobility from the less attractive areas to the more attractive ones generates, on the one hand, a progressive impoverishment of the less competitive areas and an increase in the gap with the rest of Italy; on the other hand, the inflow to the more attractive areas is not without negative consequences since, if poorly managed, it can generate major social problems [10].

Hence, just as productivity and economic growth are directly influenced by the dynamics of population evolution and thus by migration flows, the resilience to shocks of a region is also profoundly affected. An attractive region would be expected to be better equipped to cope with shocks more effectively, due to the availability of resources and expertise; on the other hand, a region that is already depleted could be hit by a shock irreversibly, with catastrophic consequences in the absence of a timely response.

In this research, this aspect is analyzed with a specific focus on the **Internal migration rate**, to effectively model the Italian case characterized by a North-South divide.

In conclusion, although it is not a widely used indicator in the literature, population change is considered to be very interesting to analyse especially in the case of Italy for the internal dynamics mentioned above.

Health Facilities

In light of the healthcare response to COVID-19 and the demonstrated vulnerabilities of the Italian system, the presence of adequate **health facilities** has emerged as a crucial area in assessing short-term resilience. The Pandemic has underscored the urgent need to remodel existing facilities to ensure their effectiveness in managing and recovering from various emergencies.

Accessibility to hospitals has played a significant role in shaping the response of different regions in fighting the virus, becoming a key factor in assessing their resilience. Peripheral areas, in particular, faced challenges due to the lack of suitable facilities, leading to difficulties in meeting the surge in healthcare demands. This situation also had repercussions on neighbouring areas, which had to accommodate residents from external areas, due to the absence of nearby facilities.

In support of this, resilience is described in the field of disaster management as "the ability of a medical facility to withstand an event while being able to maintain and expand its medical capacity and respond to sudden and significant increases in patient demand" [19, 27]. This aspect highlights an important component of a region's social vulnerability, namely the readiness and responsiveness of hospital facilities in the face of extraordinary events.

Identifying areas of resilience to minimize the negative impact of shocks and facilitate regional reorganization necessitates considering the presence of health facilities. The growing role of hospitals and emergency rooms in disaster relief over the past two decades, driven by an increase

in major catastrophes and disasters, further emphasizes their importance.

Hence, careful consideration must be given to the geographical distribution of hospitals, preferably in advance, to ensure optimal coverage and capacity to address the needs of affected individuals. Consequently, analysing the accessibility and quality of hospitals for the communities that require their services plays a key role in understanding regional Resistance and Recovery features and it is here evaluated through the extent of **hospital emigration** to other regions, to model the need for Italians to mobilise within the nation to obtain the medical care they demand.

Digital Opportunities

The digital opportunities area was selected with the explicit intent to focus on the indicator of **Remote work opportunities**.

Remote work, also known as telework, encompasses the usage of information and communications technologies (ICT), such as smartphones, tablets, laptops and/or desktop computers, which enable spatial and temporal flexibility for employees. Telework/ICT-mobile work (T/ICTM) enabled employees to perform their jobs either from home (home-based telework) or from any location on the road (mobile work).

Remote work has emerged as a significant trend in today's landscape, particularly after the COVID-19 pandemic. It offers valuable prospects for enhancing regional economic resilience by enabling work outside traditional office settings.

Prior to the Pandemic, telework was more prevalent in Scandinavian countries, while Italy had the lowest percentage of employees engaged in telework among the European countries [45]. However, the pandemic-induced restrictions in Italy led to a substantial increase in telework adoption. From being a purely emergency measure, it has turned and is still turning into an increasingly adopted working modality despite the end of the emergency. During lockdowns, telework allowed businesses and institutions to continue their operations when physical premises were closed, thus **avoiding the freezing of economic activities**. Sectors that could adapt to remote work experienced fewer disruptions during the lockdowns [10].

Remote work serves as a resource for recovery and resilience by mitigating the impacts of restricted mobility and in-person interactions. It also contributes to building a more resilient and adaptable workforce by fostering digital skills and remote collaboration abilities.

In addition to its benefits during periods of special needs like lockdowns, telework offers various advantages even in **normal circumstances**. Pre-COVID-19 studies by the Eurofound and the International Labour Office (ILO) identified **increased productivity** and satisfaction among teleworkers, who enjoy greater autonomy and flexibility in managing their working time. Telework reduces transportation costs and carbon emissions by eliminating commuting, **benefiting**

the environment and improving the quality of life. It **enhances efficiency** for firms by optimizing office space and reducing related costs, through the rotation of work desks, re-assigning those temporarily made vacant by teleworkers. Finally, telework **reduces physical barriers** to employment, enabling individuals to work from any location and supporting a more inclusive economy. This favours talent attraction and retention and gives further possibilities to people with disabilities, who may find it harder to work in a traditional office setting. Hence, despite some criticisms and disadvantages, the advantages of teleworking positively influence regional resilience.

However, the adoption of telework varies across regions and is influenced by sectoral composition and job distribution, as well as the technological preparedness of peripheral areas. Sectors like financial services and IT-related industries are better suited for remote work but may exhibit uneven geographical distribution.

The presence of an industrial structure that accommodates teleworking-compatible sectors, a skilled workforce with adequate digital skills, and a supportive physical infrastructure for digitalization can foster favourable conditions for local resilience.

Significant regional disparities in the utilization of information and communication technologies (ICTs), coupled with the varying availability of remote work opportunities, present notable challenges in transitioning to flexible work arrangements. Specifically, a clear divide emerges between rural regions, characterized by limited digital advancement and lower potential for remote work, and interconnected urban and metropolitan areas, that provide greater job prospects conducive to remote work [48].

Furthermore, the divide is also shaped by the immediate challenges of internalizing the benefits of telework, as successful digitization of business activities requires significant technical and managerial skills, that not all companies possess [43]. Additionally, companies that do possess these characteristics are typically the most productive, irrespective of their adoption of digitization and telework. Consequently, digitization has the potential to **widen the productivity gap** between companies within regions [48]. In other words, the diffusion of telework and ICT-enabled flexible work arrangements may disproportionately benefit certain locations at the expense of others. In the case of Italy, this could exacerbate the North-South divide if weaker southern regions fail to embrace this competitive evolution due to a lack of relevant digital skills and the low productivity of local firms.

Competencies

The competencies of inhabitants in a region are considered a crucial determinant of resilience. This area encompasses a deep evaluation of the existing **human capital** and its potential value in driving future growth. The competencies possessed by individuals have an immediate impact on the quality of the workforce and indirectly influence the levels of **innovation** and

entrepreneurship within a region.

To assess this area, the level of **education** was chosen as the indicator for several reasons. Educated individuals are more likely to be involved in **knowledge-intensive industries** that require high expertise and creativity, which generally are more resilient than other industries, being more resourceful, flexible and innovative. In addition, the skills required by these industries are not easily replicable by technology. They are generally hard to automate or outsource, adding real value to firms in an increasingly globalized and automated world.

Moreover, it is commonly established that there is a positive correlation between the education level of a region and **firms' productivity**, which ultimately leads to higher resilience for the regional economy [93]. The level of education also has a correlation with business presence in the region in a mutually influential way. As a *chicken-and-egg* situation, higher levels of education lead to more enterprises and higher productivity in the area and, in parallel, a more developed and productive environment attracts people with higher skills and education. Therefore, the most productive regions are also the most educated and vice versa.

In light of the aforementioned reasons, it is of paramount importance to verify that these concepts are also valid in the context of short-term shock responses.

In the **economic dimension** of resilience, selected areas are:

- Innovation;
- Diversification vs. Specialization;
- Agglomeration economies;
- Connectivity & access to digital network;
- Access to transportation network;
- Financial condition.

Innovation

Innovation is crucial for firms' competitive advantage and, more generally, for economic development. Indeed, its significance extends beyond individual firms to encompass the entire economic system, allowing for a distinct recognition of private and public benefits it brings forth.

Private benefits of innovation can be traced back to higher profits for the innovative firms as they can obtain a premium price, namely selling the innovative products at higher prices on the market, or/and gain higher profits by decreasing their production costs by boosting the efficiency of their process innovation.

Public benefits of innovation are related to the positive externalities that innovation generates on consumers and other firms. For the former category, these advantages are usually related to greater consumer surplus, arising when consumers' willingness to pay for innovative products increases more than the products prices. For what concerns other firms, innovation, despite being a competitive weapon (it may reduce competitors' profits), may also generate higher profits for extant firms producing complementary assets for innovative products/services or for those imitating innovators and exploiting their knowledge spillovers. In this way, innovation may also foster entrepreneurship and the rise of new firms, job creation and growth. Evidence exists that the public benefits of innovation outweigh the private benefits for firms (i.e. the social optimal level of innovation is higher than that pursued by firms based on the optimization of their personal benefit).

Therefore, the importance of innovation for the economy is undisputed. The question at this point is to what extent innovation is important to resilience according to a short-term perspective. What happens to innovation during a shock? The response of firms to an economic downturn in terms of their innovative behaviour could be divided into three categories:

- the *cyclical behaviour* for firms decreasing their investment in innovation in times of major economic downturns;
- the *persistent behaviour* for firms maintaining their innovation investment despite the downturn;
- the *countercyclical behaviour* for firms deciding to invest even more in innovation during periods of severe economic depression [9, 51].

Reducing investments could be a natural reaction of prudence, so as to contain costs and preserve liquidity during periods of economic uncertainty, due to a drop in domestic and external demand and the limited strength of the credit system. Although this strategy may at first glance appear to be the right choice in the short term, it could lead to major problems in the long run in terms of losing competitiveness and being "left behind" in an evolving and innovating world. In this sense, *persistent behaviour* recognises the importance of technological accumulation and companies adopting such strategies recognise the importance of innovation as a key factor for long-term success and maintaining competitiveness. Continuing to invest in innovation during the crisis could allow them to gain competitive advantages once the economy recovers. Or even, a *counter-current behaviour*, i.e. increasing investment during an economic downturn, could allow them to capitalise on the current situation, e.g. by having access to resources or talent at a lower cost, strengthening their market position.

In essence, just as the pre-shock rate of innovation is an important lever for greater resilience for the private and public benefits outlined above, the level of innovation that firms maintain during the shock itself is also thought to contribute to the recovery. Thus, even though measuring the

level of pre-shock innovation is useful in order to understand the different tools available to regions before a shock occurs, it is also relevant to measure how a different innovation response during a shock allows regions to cope with a swifter recovery at the macro level, stimulating economic growth and job creation.

To conclude, this area is at the focus of policy intervention and should also be in the crosshairs of a region's resilience analysis, to further understand the impacts innovation may have in its response to disruptions in the short-term. The level of innovation in different provinces is assessed based on the respective **patents intensity**, reflecting the degree of active engagement in inventing new technologies, processes, or products able to boost the efficiency of the already existing ones.

Diversification vs. Specialization

In line with what has been previously discussed during the literature review about the usage of this area, the role of **specialisation or diversification** in regional economic resilience is a matter of debate. In particular, it is not clear from the literature whether high specialisation is a positive or negative factor for the region in terms of resilience, or whether it is possible to make point-by-point considerations for individual sectors or not, since the results between different studies are often conflicting.

This difference of thoughts strongly suggests including this indicator in the model and thus focusing on the **sectoral composition** of regional economies, that is the mix of industries in the region and the purchaser-supplier relationships among these activities. Indeed, it is intuitive to think that differences in the sectoral composition of regional economies contribute to the spatial variation in the severity of the shock impacts. Especially in countries such as Italy, investigating the role of structural differences between regions may prove crucial. In fact, Italian regions often have very different economic structures and there are important realities to recognise. For instance, **industrial districts** are a significant phenomenon. They can be found in several Italian regions and represent a relevant part of the country's economic fabric. They are geographical agglomerations of companies operating within a specific sector or related sectors. Hence, their presence demonstrates a specialized regional economy. Nine different specialisations of industrial districts are identified by ISTAT:

- Textiles and clothing;
- Leather, leather and footwear;
- Household goods;
- Jewellery, goldsmiths, musical instruments, etc.;
- Food industries; Mechanical engineering;

- Metal industries;
- Chemical, petrochemical, rubber and plastic products;
- Paper and printing industries [80].

Italian industrial districts are known for promoting cooperation and synergies between firms, fostering competitiveness, innovation and efficiency. Firms within an industrial district often share resources, knowledge and suppliers, creating a favourable environment for economic development.

For similar reasons, being a region hosting an industrial district could play a role in the response to a shock. Their presence contributes to the differences between Italian regional economies. In fact, industrial districts are a predominantly North-Italian reality and, in this sense, may contribute to exacerbating the **North-South divide** and determining different levels of resilience between regions.

The role of the industrial district has already been evaluated in resilience studies both in [35] and in [49]. The latter showed that being part of an industrial district in two of Italy's most traditional sectors, food and textiles, has been a relevant and useful element in fighting the economic recession.

In addition, further evaluations can be made on the specific kind of specialization. For instance, a region with a strong touristic vocation in Italy can be expected to be highly resilient. Similarly, an agricultural designation could also be a positive factor, with food being a very inelastic good. So, the different geographical distribution of sectors could be deeply relevant in explaining spatial differences in the resilience of regions. However, it is crucial to emphasise that much will depend on the nature of the crisis and its impact on different sectors, which may vary greatly. Considering the COVID-19 pandemic and its highly disparate effects on the economy, many sectors experienced a sharp drop in demand and turnover, while others experienced growth and increased employment. For example, the tourism sector was one of the hardest hit by the Pandemic, as government measures to contain the spread of the virus, such as closures or, more generally, obstacles to people's mobility, led to the suspension of events, travel and holidays and the associated consequences. The same did not apply to the technology sector, which was one of the least affected by the Pandemic. On the contrary, the latter in some cases even experienced growth, as in the case of some technology companies offering e-commerce, videoconferencing and remote working services, that have experienced a decisive increase in demand.

In conclusion, it has already been pointed out by other authors that more studies on the relationship between specialisation and resilience are needed, to help policymakers implement policies and reforms that can mitigate the effects of the recession and provide the basis for sustained and stable regional economic growth.

In this context, the indicator chosen for assessing specialization and diversification is a Relative Diversity Index, to compare the diversification level of the economies of Italian provinces.

Agglomeration Economies

Given the number and depth of contributions that have been made to this area in the literature and the already discussed controversial nature of its contribution to resilience, the presence of **agglomeration economies** in the region examined is certainly a further element to be considered in the analysis of short-term resilience. As mentioned previously, agglomeration dynamics can indeed generate a complex interplay of benefits and drawbacks within a region. These factors often exert an influence on its resilience during times of crisis, in a non-negligible way.

Going more in-depth with **urbanization economies**, the grouping of businesses and people close to each other in cities or regions enables wider access to skilled labour, suppliers, and infrastructure, as well as lower production costs. This fosters the growth of particular practices that are specifically suited to that configuration and flow through this area of economic activity, making them particularly stable and capable of adaptation.

Moreover, this usually fosters the **collection of knowledge** and the exchange of fresh and creative ideas between companies, which enables the region to achieve what economists refer to as "increasing returns for scaling customers with similar characteristics". Consequently, areas with greater diversification might exhibit a smaller crisis impact [35, 87]

More precisely, the benefits that urbanization economies can bring mainly concern 3 areas:

- **Transportation**: the proximity between different firms makes travel much easier and faster, greatly reducing the transportation costs associated with it. This can enable firms within the area to gain comparative and cost advantage over foreign competitors, increasing their strength and resilience
- **Knowledge**: the closeness of many different and sometimes complementary firms allows experts and knowledge to be concentrated in a circumscribed area where they can be cultivated and increased through the continuous and fostered exchange of information and know-how among different players. This accumulation of knowledge and human capital not only benefits individual firms but also gives added value to the whole area, facilitating knowledge generation and diffusion.
- **Labour**: urbanization economies often increase the attractiveness of the area and consequently become pools for talent, both for the region and externally. This arguably contributes to better economic matching, e.g. between buyers and suppliers or between employees and employers, thereby making the local economy function more smoothly and the reaction to shocks more efficient.

The combination of these dynamics may increase efficiency, innovation, and productivity for specific enterprises, as well as benefit the industry as a whole by enticing new participants into the market and encouraging development.

However, urbanization economies do not only lead to benefits but are sometimes associated with **negative features** of urban centres, a factor that makes the need to include and investigate this aspect in the study even more evident. They frequently lead to traffic jams, pollution, and other adverse externalities which are ultimately responsible for diseconomies of scale that, in disciplines or sectors with restricted access to necessary production facilities or resources, translate into increased crowding and longer wait times. Similar elements, together with the high number of rivals present in the area, weaken companies' ability to set prices, creating intense competitive pressure. With this regard, while strong competition leads to market price reductions, which encourage firms to innovate and increase productivity, excessive rivalry is likely to hinder business growth and creativity, leading to some social problems as well.

Moreover, in addition to the evident environmental consequences deriving from the co-location of numerous individuals and industries in the same area, it has been demonstrated that agglomeration economies exacerbate **intra e inter-regional disparities** by boosting inequality both within urban areas and between urban and rural areas. In fact, these regional disparities have been made worse by the health and economic upheaval brought on by the COVID-19 pandemic [12]. This is especially concerning because regional differences within nations have not decreased since the 2008 financial crisis, and the current recession may potentially accentuate these unequal spatial patterns in many significant economic and social areas [48]. Indeed, the majority of regions including urban areas and farther-flung locales, have seen stagnation or drops in GDP and productivity [48]. The only group of regions that has had GDP growth relatively rapid in recent years is composed of those that are close to urban centres: this suggests the necessity to go deeper into the reasons underlying this trend and it points out once more the relevance of urbanization economies in similar contexts.

It is precisely the aforementioned conflict between urbanization economies and urbanization diseconomies that can either facilitate, impede, or hinder local growth, indirectly but significantly affecting regional resilience, even in its short-term phases. Hence, a measure of the **Urbanization degree** is decided to be included among the model's independent variables.

Connectivity & Access to Digital Network

Connectivity is believed to be crucial for the Resistance and Recovery phases for several reasons. Firstly, focusing on immediate response to shocks, connectivity, and thus access to digital and communication infrastructures, allows people to access information and services and to communicate even during emergency situations. In this way, it avoids business stoppages, thanks to the flexibilities introduced by digital technologies such as the ability to work from

home. It also avoids the complete disruption of fundamental services such as teaching, as we were able to experience during the Pandemic, and it enables the, more or less, rapid response of Italian schools and universities with the adoption of distance learning.

However, the benefits are not limited to the immediate response to shocks interrupting mobility. In fact, connectivity has substantial impacts on the productivity and competitiveness of regions. Particularly, when there are few or no digital infrastructures, it may be more challenging for individuals and firms to access online services and resources, which would make it harder to engage in the digital economy. Organizations may struggle to connect with their clients and suppliers online, which hinders their ability to engage in effective competition. Additionally, businesses in these regions are generally less appealing and may have trouble finding suitable employees. These regions' human capital may also suffer a negative impact. People who suffer this "**digital distance**" may find it challenging to access information, educational programs and training possibilities, including online courses, job information and the like, which restricts their ability to learn new skills and engage in new initiatives.

For similar reasons, a heterogeneous spread of connectivity between regions leads to a different response when faced with any emergency situation. Therefore, when analysing the economic resilience of regions, it has to be taken into account the disparity in access to digital and communication infrastructures and technologies, i.e. the **digital divide** between regions. Indeed, there are geographical areas, especially in mountainous areas or far from urban areas, that may have limited or no Internet coverage, spreading inequalities in participation in the digital economy and access to information. For this reason, acting on the digital divide is one of the European objectives, promoted for instance in the Digital Agenda for Europe, whose goal is to ensure digital access and equality throughout Europe.

However, Italy still shows geographical disparities and the digital divide is a problem that still affects many people and territories. Urban areas and large centres are generally better served by digital infrastructures, while peripheral areas often still lag behind in access to high-speed Internet connections. According to ISTAT data, in 2020 34.3% of Italian households did not have access to a high-speed Internet connection and 24.2% of Italian households did not have access to a computer. These percentages are still very high considering how today's society is moving and evolving, so the digital divide represents a significant threat to the competitiveness of the economy and social inclusion in Italy.

During the **COVID-19** pandemic, the digital divide was an even more urgent and critical problem, since it affected the recovery of part of the population. It is reasonable to assume that the digital divide hindered the use of remote work as a tool for rapid recovery during COVID-19. Without a reliable and fast Internet connection, working from home can be difficult or even impossible. This can limit workers' **productivity**, particularly at a time when remote work has become increasingly important due to the Pandemic. Similarly, many students found it difficult to participate in distance learning due to insufficient or no Internet connection, which

limited access to education and increased the learning gap between students with different levels of access to technology.

The resilience of regions, therefore, is supposed to be closely linked to the level of connectivity and deserves to be investigated more deeply. In this research, the indicator chosen to track this area is the **Ultra-broadband penetration**, in order to express the digital inclusion in terms of distribution of similar technologies.

Access to Transportation Network

Despite the lack of relevance in the literature, it was decided to include as an area of regional economic resilience the **accessibility to transportation network**. Indeed, in recent years there has been a growing interest in economies intended as networks of people, enterprises and institutions, in which the various actors interplay and participate, creating a complex interactive system where links evolve through learning processes between the actors involved. In this sense, spatial analysis becomes fundamental to map the structure and evolution of such a system, and access to transport becomes primary to capture all possible relationships and points of contact [108]. Since it makes it easier to transfer people and things from one location to another, the transport system constitutes the backbone of any economy, being closely intertwined with the knowledge flow within a region. **Greater connectivity** gives regions with superior transportation systems access to new markets, technology, and opportunities both within the region and outside of it, increasing regions' ability to be reactive in the event of adversities.

In general, it may be argued that geographical proximity plays a key role in enabling knowledge among players since **knowledge spreading** is tied to human contact and movement: in this sense, being able to conveniently and quickly access means of transport can make a region more equipped to adjust and react to changing conditions. Another important aspect to consider is the linkage between job and transportation accessibility: having a more functional and effective transportation infrastructure makes it smoother the work-home commute, enlarging the talent pool available for the region. This is crucial for areas that depend significantly on specialized industries, like manufacturing or technology. On the contrary, an area may find it difficult to recruit the labour and knowledge needed to support its economy, if it has poor transportation connections, making it more susceptible to shocks.

Transport infrastructure systems also play a key role in the distribution of goods, enabling or restricting their movement within and between regions. As they provide a network of operations to support the mobility of people and goods, they connect businesses and support supply chains and services. This is especially crucial for areas that depend heavily on exports or have sizable manufacturing bases. A region's ability to compete in the global market may suffer if its transportation system is underdeveloped.

Moreover, regions with good transit alternatives are more likely to lure tourist traffic, which might be a substantial source of financial resources. Indeed, the ease of travelling to and from a location, as well as the comfort of exploring the area while being there, may be facilitated by good transport connections. This can strengthen a region's ability to absorb declines in other industries and, at the same time, promote **economic diversification** in the area.

In addition to providing access to vital resources for daily activities, accessibility to transport becomes particularly important in emergency circumstances. In the latter case, transport infrastructures play a key role in the evacuation of survivors, rescue operations and community reconstruction and recovery. At the same time, transport systems are particularly susceptible to shocks and exposed to the risk of a wide variety of hazards, ranging from natural events and technological failures to intentional malicious acts. In addition to direct damage to the physical transport infrastructure and the expense and energy that must be expended to renovate it, they often involve indirect but equally, if not more, impactful damage. That is, disruptions in the operation of these systems often have cascading impacts within the system and on other interconnected critical lifelines, creating long-term socioeconomic and psychological effects.

This aspect emerged with particular brutality during the **COVID-19** pandemic and made clear the need to include this factor in the analysis of resilience. During the Pandemic the reduction in mobility has often been an obstacle to work for a large part of the population who found themselves excluded from essential sectors identified by the government and/or prevented from teleworking/smart working. The dynamic during a pandemic is not dissimilar to that following a natural disaster, in which mobility and transport networks are rendered useless by an unexpected event and the population is forced to coexist with exceptional measures that reduce their ability to move and work. The difference, in the case of the lockdown imposed to contain the spread of COVID-19, lies in the scale of the event, concerning the entire Italian territory regardless of the actual level of contagion.

In this context, it is intriguing to be able to connect the responses of various locations to the same (or comparable) decline in mobility to transportation accessibility prior to the Pandemic. With this regard, the alteration in mobility really serves as an instantaneous approximation of the economic harm experienced by a particular geographic location [10].

Finally, the relevance of considering access to transportation networks has been heightened by the recent unprecedented increase in the frequency of disasters, both natural and man-made, widespread urbanisation and the increased complexity and interdependence of systems, which has intensified the impact of such events on transport systems [50], making this aspect impossible to be overlooked.

Given these premises, the indicator chosen to account for this area is the **speed of public road transport**, for the awareness of speed as a good measure of the efficiency of the public transport system.

Financial Condition

Although it has not yet been thoroughly investigated, the region's **institutional framework** shows all the good prerequisites to bring a relevant contribution to the analysis of resilience that cannot and should not be forgotten. Institutional systems can be in fact exposed to shocks that, given their intended function, may directly affect the ability of regions to forge new economic trajectories and, therefore, influence their regional resilience.

According to Boshma, institutions like laws, conventions, and cultural attitudes, are directly related to both the techno-industrial variety and networks since they are responsible for allowing or hindering exchanges between the region's businesses and local knowledge base [15], thus playing a pivotal role in shaping the region's innovation ecosystem and determining its overall competitiveness.

Moreover, because institutions have a significant historical and path-dependent component, they can be connected to the trade-off between adaptation and adaptability. When new sectors emerge, new institutions spring up to fill a specific demand, but once these institutions are established, they might obstruct the creation of new growth routes due to institutional inertia and hysteresis.

All of the aforementioned factors highlight the necessity of examining the institutional structure, which will be specifically done by taking into account the *financial condition* area. In particular, the selected indicator can be defined as **Administrative Budget Balance**, representing the administrative surplus (or deficit) in relation to the current revenues of Italian provinces administrations.

The decision to consider this area is intended to complete the analysis perspective and complete the view on regional **socio-economic disparities**. Indeed, in Italy, the financial autonomy of municipalities gives them the power to manage their own revenue and expenditure, albeit subject to the constraints set centrally by the national government. Most of the regions' revenues are resources allocated to finance health and hospital facilities, which are therefore not offered to Italian citizens evenly and equally between regions and thus provinces. This disparity played an important role during the health emergency brought about by the COVID-19 pandemic and even now generates daily mobilisations of citizens from the most marginalised areas and less equipped regions moving across the peninsula for better health services.

However, the disparities are not just in terms of health services, but, in more general terms, the provincial expenditures and investment choices are differentiated from one region to another. Hence, a disparity in financial strength and availability of means leads to major **inequalities** between regions. The differentiation between provinces in terms of financial self-sufficiency is at the root of their economic and development gap and thus the quality of life of their inhabitants. In conclusion, it could be a key element in shaping regional response and resilience disparity.

Finally, the selected areas within the **environmental dimension** of resilience are:

- Seismic risk;
- Soil condition;
- Waste sorting.

As evident, the macro aspect concerning pollution was ultimately not selected. This is primarily attributed to two factors: on one hand, while pollution could influence people's health and consequently their disease resistance, the relationship might be intricate and influenced by numerous other factors. On the other hand, given that pollution is a factor that yields long-term effects, the consequences might not be discernible within the analyses of the 2018-2022 quinquennium. Hence, the decision was made to exclude the pollution level from short-term analysis.

Seismic Risk

Italy is a country with a high **seismic risk** and, despite this situation being widely acknowledged by both the population and policymakers, the country has repeatedly demonstrated that it is unable to respond effectively to possible earthquakes so as to minimise the resulting physical and intangible damage. In particular, the unpreparedness of institutions at all levels became explicit after the seismic events that struck Abruzzo, Lazio, Marche and Umbria starting on 24 August 2016. In just six months, in fact, the damage and costs were estimated at around EUR 23 billion [109].

Earthquakes, especially those of high intensity, are often regarded as occasional calamities and consequently addressed only when they actually become emergencies, without considering the possibility that such events may be repeated over time. However, it was precisely **COVID-19** that dramatically reminded us that events as rare as pandemics, which we often tend to forget, can actually occur and can return with a much higher magnitude than we have seen in the past. This underlines once again the need to be prepared in advance for possible shocks: it is crucial to have well-defined plans and programs that instruct populations on appropriate actions during such occurrences, thereby preventing them from being caught off guard.

Analysing the seismic risk in Italy in more detail, the entire national territory is subject to earthquakes, but the most intense ones tend to occur in specific areas: in the north-east (Friuli Venezia Giulia , in western Liguria, along the northern Apennines (from Garfagnana to Rimini), along the central and southern Apennines, in Calabria and eastern Sicily [63]. This is of particular relevance because, although it is not possible to predict with certainty when, with what intensity and where an earthquake will occur, being aware of the most dangerous areas involved and the associated potential consequences, is the best guarantee for preventing and reducing the consequences of an earthquake

According to official Italian government guidelines, Seismic risk measures the expected damage over a given period of time, based on the type of seismic activity, building resistance and human activity and, in order to precisely evaluate it, [63] it is necessary to take into account the region's mix of danger, vulnerability, and exposure. The area's seismicity, or how frequently and strongly earthquakes occur there, determines the level of **danger**. The definition of **vulnerability** of a region is its susceptibility to harm: the effects of an earthquake are inversely correlated with the degree of a region's susceptibility. Last but not least, **exposure** describes the existence of resources that are vulnerable to seismic risk, such as population density and the presence of historical, cultural, and architectural property. Overall, Italy presents a medium-high damage risk (in terms of frequency and intensity of phenomena), a very high vulnerability (due to the fragile nature of buildings, infrastructures, industrial, productive and service assets) and a very high exposure (due to population density and the presence of a unique historical, artistic and monumental heritage). Because of this, the danger of an earthquake on the peninsula is considerable in terms of casualties, property damage, and direct and indirect expenditures.

Looking at the data, however, what emerges is the high earthquake-related mortality in Italy, especially when compared to that of territories with higher seismic risks, such as California and Japan. The efficiency and the low number of fatalities recorded in Japan suggest that the earthquake prevention model adopted by that country is an example to follow. As one of the countries most affected by earthquakes, indeed, Japan has developed a rigorous system of infrastructure regulations and invests a significant amount of its budget in earthquake prevention. It has also implemented solid education for the population, achieving excellent results.

This illustrates the importance of taking seismic risk into account in order to identify **vulnerable structures** and **sensitive locations** and put the appropriate mitigation strategies and preparation measures in place. Using this information to select suitable locations for significant structures, engineers and planners may also include measures to ensure the resilience of infrastructure. Moreover, risk evaluation, insurance coverage, and community education about seismic dangers all depend on seismic risk analysis. In fact, it aids individuals in strengthening their personal safety by assisting them in understanding possible hazards and taking the required safety measures.

Soil Condition

In the current context of accelerating urbanization and increasing climate change, the consideration of **soil condition** has become imperative for resilience assessment. This necessity, coupled with renewed attention to hydrogeological risk, is reflected in the inclusion of €15.06 billion in the PNRR for "Protection of the Territory and Water Resources" out of the total €59.47 billion allocated to the Green Revolution and Ecological Transition, one of Italy's 6 missions aimed at contributing to the achievement of climate, environmental, and energy objectives established at the European level [62].

The urgency of this issue was recently underscored by the **flooding in Emilia Romagna** in May 2023 and the subsequent consequences of these tragic events. While the increase in extreme weather events and the environmental crisis partially contribute to such occurrences, it is essential to highlight the extent to which human site selection for construction has contributed to the severity of these emergencies. Despite Italy being identified as one of the most exposed countries in Europe to the climate crisis by the World Weather Attribution [3], analyses have raised doubts about the direct link between the severity of the consequences of this flooding event and the climate crisis alone.

Indeed, the most significant impact appears to be **excessive urbanization** and **inadequate land management**: the construction of infrastructure in hydrogeologically complex areas, such as the obstruction of watercourses or building on risky terrain, has adversely affected the soil's capacity to absorb precipitation and safely channel water. Therefore, the root cause of such catastrophic events can be attributed to soil conditions.

The relationship between hydrogeological risk and soil condition seems intricately intertwined, with overlapping aspects. Consequently, our focus will be directed toward evaluating one of these two aspects, specifically soil conditions.

In particular, **Land consumption** is considered the most representative indicator in this area. Illustrating how land is utilized by humanity is determined by the growth of areas covered by inhabited buildings and other structures, as well as its utilization for infrastructure and transportation links [1].

This is a particularly relevant indicator in the study of Italy's short-term resilience. Indeed, in addition to its intrinsic inclination towards territorial instability, Italy is a highly anthropic country. This contributes to the abandonment of mountainous and hilly rural areas in favour of urban expansion, which in turn leads to neglect in the preservation and maintenance of natural territory and its subsequent fragmentation.

Furthermore, the increase in urbanized regions following the Second World War, often lacking effective territorial planning, has increased the number of components exposed to risk, such as goods and people in vulnerable areas susceptible to landslides and floods. Additionally, the growth of artificial surfaces, which has risen from 2.7% in the 1950s to 7.11% in 2020 [121], has further heightened the frequency of so-called "flash floods" - sudden and rapid inundations, already been exacerbated by the climate crisis - to which the Italian territory is particularly exposed.

Moreover, data on land consumption are among the most commonly requested for the planning of sustainable management plans for Italy's landscape and environment. Excluding this area from the resilience drivers assessment would mean ignoring a field that guides the management choices of regions.

To further emphasize the importance of soil health and the resulting influence of land consumption on territorial resilience, Europe and the United Nations have set the goal of zero net land consumption by 2050 [46], subsequently highlighting the need to develop best practices to mitigate the negative effects of land sealing, an irreversible process that primarily weakens Italian territory and makes it vulnerable to shocks.

Waste Sorting

Despite the seemingly great concern about the consequences of today's consumerist and wasteful lifestyles, the area of **waste sorting** is surprisingly insignificant in the literature. However, the decision to include this area has a solid foundation.

First of all, waste is a more or less direct indicator of **anthropogenic impact**. In fact, it is a distinctly anthropogenic phenomenon: in nature, everything that is produced and needs to be expelled is also entirely reused within the natural cycles themselves; this is not the case for urban waste [67].

Therefore, how urban realities manage, dispose and possibly recycle waste is a relevant measure of environmental impacts. Incorrect waste management can lead to disastrous consequences for local areas in terms of air and water pollution and bring with it a series of side effects such as endangering the public health of citizens or compromising the main engines of local economies. Emblematic is the case of several areas with a strong tourist vocation in southern Italy, characterised by small municipalities that have historically based their livelihoods on summer tourism but are experiencing severe crises and declines due to increasingly polluted seas and beaches submerged by waste.

Moreover, in emergencies, the huge production of waste and its improper management makes urban systems vulnerable, which can be subjected to exceptional and uncontrolled pressures with situations close to collapse.

For example, the **COVID-19** pandemic also raised concerns about **contamination risks** associated with waste management. During the spread of the virus, a large increase in various clinical wastes such as masks, gloves, personal protective equipment etc. was observed, which, when contaminated with normal municipal solid waste, risked increasing the risk of virus transmission. This problem highlighted the importance of proper waste collection and disposal [56].

But, beyond the emergency dynamics, waste management is to be considered a key topic in light of current and very intense growth and consumption rates. Indeed, waste generation will continue to increase and, at current rates, is expected to reach a dangerous peak at the end of the century [77].

The relevance of this issue is also supported by the PNRR, which includes among its objectives, specifically as part of Mission 2, the one of improving waste management through the mecha-

nisation of waste collection and the creation of additional waste treatment facilities [1], also in order to reduce the number of European infringements opened against Italy, and of lessening the important regional disparities in separate collection rates. The explicit reference to waste management and differentiated collection within the objectives of the National Recovery and Resilience Plan reiterates the high strategic importance of a change of course in this respect for Italy [5].

The topicality of the issue is also confirmed by the Italian government's awareness of significant regional disparities, in particular between northern and central-southern regions (today about 1.3 million tonnes of waste are treated outside the regions of origin) [62]. The absence of a clear and consolidated national strategy for waste management and the transition to a circular economy suggest that there is much room for improvement and keeping this factor under control can be crucial in terms of resilience.

Diffusion of Urban Waste Sorting serves here as the indicator of the Waste Sorting area, reflecting the presence of sustainable waste management practices.

[1] Avviso M2C1.1 I1.1 Linea A - "Miglioramento e meccanizzazione della rete di raccolta differenziata" dei rifiuti urbani, contemplata nell'ambito della Componente 1 "Economia circolare e agricoltura sostenibile" della Missione 2 "Rivoluzione Verde e Transizione Ecologica"

4 | Data collection

The aim of the **Data Collection** process is to build a robust and comprehensive **database** that serves as a firm foundation upon which to construct and evaluate the model. With this in mind, an adequately extensive amount of **quantitative observations** for each year within the chosen time frame and for every territorial unit under analysis was searched and collected.

As a result, the database assembled information about each NUTS3 Italian region, concentrating on the five-year timeframe 2018-2022 to encompass the pre-shock and post-shock scenarios.

However, in order to enhance the comprehensiveness and coherence of the analysis, the data subsequently underwent a reprocessing and cleaning procedure to enhance their comparability and relevance.

This entire process is visually represented through the assistance of a flowchart in Figure 4.1, whose distinct phases are further explored individually below.

4.1. Data Research

To investigate the wide array of themes related to the temporal trends in **social, economic, and environmental aspects** of Italian provinces this thesis exclusively relied on **secondary data sources**. The decision to exclusively employ secondary sources was driven by the complexity and vastness of the research problem, necessitating a **multidisciplinary approach** to explore heterogeneous phenomena and dynamics. The utilization of primary data, such as interviews or surveys, would have imposed significant limitations and constraints on the coverage of diverse dimensions under investigation, particularly hindering the potential for result **generalization**.

Moving to a more detailed analysis of the **sources** and **instruments** employed, the acquisition of secondary data primarily relied on the consultation of **public databases**. Among the main sources utilized, the **ISTAT** (Istituto Nazionale di Statistica) provided relevant and up-to-date statistical data on various aspects of the Italian reality, including demography, economy, industry, internationalization, and environment. The **ISPRA** (Istituto Superiore per la Protezione e la Ricerca Ambientale) proved indispensable for environmental data, climate change, and pollution, enriching the research with crucial information for understanding environmental trends. **EUROSTAT** (Statistical Office of the European Union) offered a comparative perspective, sup-

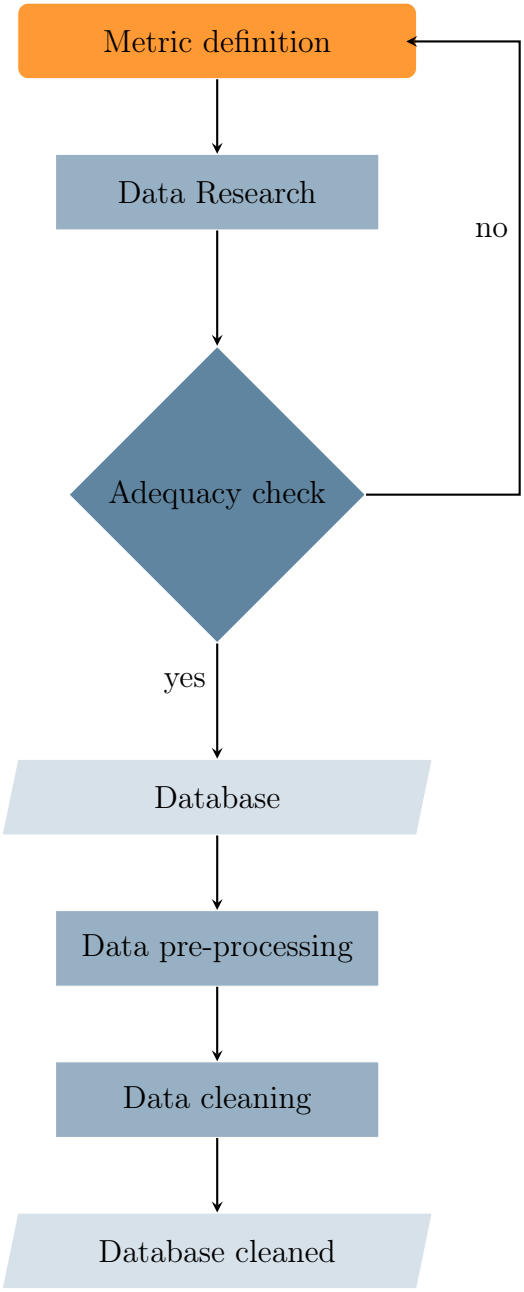

Figure 4.1: Data Collection flowchart.

plying socio-economic, environmental, and demographic data. Lastly, the **AGCOM** (Autorità per le Garanzie nelle Comunicazioni) constituted an authoritative source for investigating the communications and media sector in Italy, providing relevant and updated data and analyses within the context of technological and connectivity innovation.

It should be emphasized that accessing these sources was straightforward, as they are of a public nature and freely accessible. However, obtaining certain specific information necessary for the current research was not always exhaustive or readily available.

For this very reason, before commencing the actual data collection, once an initial indicator proposal had been established, an **availability** and **suitability** check was conducted to either confirm the final selection or to consider an alternative indicator should the need for a different choice arise.

In some cases, the data adopted a territorial analysis unit with a higher level of granularity, which necessitated a **weighted aggregation** to maintain the consistency of the choice of the NUTS3 territorial analysis unit. In other instances, the use of **proxies** for certain variables was necessary to fill potential informational gaps, while maintaining a rigorous methodological approach to avoid distortions in the research.

In any case, this process required careful assessment and the adoption of strategies for **re-processing** the original data, ensuring the consistency and appropriateness of the information for achieving the research objectives and analytical purposes.

Table 4.1 summarises the final selected indicators/proxies, the respective metrics used to measure them and the data sources employed to construct them.

4.2. Data Pre-processing

Throughout the course of this research, the presence of **missing or incomplete data** over the temporal scope of the investigation has been encountered. This partial incompleteness of the data could be attributed to various reasons, such as the absence of data for certain years or specific periods, the unavailability of updated information, or other limitations in the consulted sources. To address this challenge and ensure a consistent and coherent analysis, a technique for estimating missing data based on time series was adopted, leveraging the support of **Excel** software.

The utilized approach proved to be simple, rapid, and effective, enabling the generation of reliable and coherent estimates aligned with the available data. Firstly, **historical time series** related to the variables of interest were identified, encompassing dependable and quasi-continuous data across a specific timeframe. Subsequently, a forecasting technique grounded in the analysis of past trends was employed to estimate the missing data within the examined time series.

Independent var.	Metric	Source
Structural dependency ratio	% of non-working age population (0-14 years and 65 years and over) to working age population (15-64 years).	ISTAT
Internal migration rate	Ratio of the year's internal migration balance to the average amount of the resident population, multiplied by 1,000.	reprocessed ISTAT data
Hospital emigration	% of hospital discharges made in regions other than the region of residence out of total discharges of residents in the region.	ISTAT
Propensity to remote work	% of enterprises providing more than 10% of their employees with mobile devices with a mobile connection for work purposes.	reprocessed ISTAT data
Education level	% of the population with a tertiary level qualification.	reprocessed ISTAT data
Seismic risk	Value of horizontal ground acceleration estimated to occur or be exceeded with a 10% probability in 50 years, evaluated on rocky and flat ground, and expressed as a fraction of the acceleration of gravity (1g=0.981 cm/s2).	reprocessed INGV data
Land consumption	Change rate from non-artificial land cover (non-consumed soil) to artificial land cover (consumed soil), with the distinction between permanent land consumption (due to permanent artificial land cover) and reversible land consumption (due to reversible artificial land cover).	ISPRA
Waste sorting diffusion	% of selective waste collection as separately collected urban waste on total urban waste.	ISPRA
Patent intensity	Number of patents issued per million inhabitants.	UIBM
Relative diversity index	Inverse of the Herfindal index computed with the ratio of the employment per section of economic activity per territorial unit (province) over the total employees per territorial unit.	reprocessed ISTAT data
Urbanization degree	Degree of urbanisation of municipalities (based on the criterion of geographical contiguity and minimum density and population thresholds) weighted according to the surface area of the municipalities.	reprocessed AGCOM data
Ultra-broadband penetration	% of resident population having ultra-broadband subscriptions.	reprocessed ISTAT data
Public transport speed	Average commercial speed per km of public road transport (buses and trolleybuses).	ISTAT
Administrative budget balance	General government surplus or deficit over the current revenue from taxes, contributions and equalisation, current transfers and extra-tax revenue.	ISTAT

Table 4.1: Independent variables of the Resistance and Recovery models and respective metrics and sources.

The utilization of historical time series as a foundation for forecasting is a **robust approach**, as these data hold valuable insights into the past fluctuations and dynamics of the variables under

scrutiny. By identifying patterns and prior trends, the Excel software facilitated the generation of forecasts for the missing data points, effectively bridging the informational gaps within the research's temporal horizon.

This process of estimating missing data contributed to ensuring greater completeness and consistency in the analysis, enabling the incorporation of pertinent and meaningful information in the treatment of the considered social, economic, and environmental trends. Nevertheless, it is crucial to emphasize that, while a valid technique, the forecasting approach based on historical time series does carry inherent limitations. Its reliability is heavily influenced by the stability and regularity of historical data and the reference conditions used for making estimations. For this reason, the decision was made to employ this tool exclusively in cases where missing data pertained to **non-critical years**, i.e. years far from the shock, which presumably presented values different from those that could be predicted.

Despite these considerations, the adoption of this methodology proved fitting for the research context, offering a pragmatic solution to address the challenge of missing data and ensuring a uniform and precise treatment of the analyzed temporal trends. The choice to employ Excel software as a supporting tool streamlined the method's implementation, allowing for efficient and systematic management of the historical time series and conducted estimations. Ultimately, the adopted approach facilitated the transcendence of limitations posed by available data sources, ensuring a more comprehensive and dependable analysis of the research theme.

The pre-processing procedure proceeds with the **Min-Max normalization** of the data through Excel. The Min-Max transformation can be employed to achieve a standardization that preserves the data order and renders them comparable among themselves. This is particularly beneficial when variables exhibit disparate scales and distinct units of measurement.

Normalization enables a direct comparison of the impact of different variables on the outcomes, mitigating the undue influence of a dominant variable on the analysis. This contributes to enhancing the future performance of the model utilizing the manipulation of the aforementioned dataset. Specifically, it facilitates an initial reduction in the impact of outliers before the actual data-cleaning process described subsequently. In fact, Min-Max normalization diminishes the impact of outliers by transforming data into a bounded range. This aids in better-managing data with anomalous or outlier values, preventing them from unduly skewing the analysis. Throughout this process, the relative proportions among the data are preserved, thus upholding the underlying relationships between variables. Only the data scale changes, without altering the structure and underlying relationships. Consequently, this procedure enables a **simplified interpretation**.

The formula adopted was as follows:

$$\text{Standardized values} = \frac{x - \min(\text{Values})}{\max(\text{Values}) - \min(\text{Values})}$$

Where:

- x represents the original observation being standardized;
- min(Values) denotes the minimum value among all observations of the same variable;
- max(Values) signifies the maximum value among all observations of the same variable.

4.3. Data Cleaning

Before transitioning to the modelling phase, the data must undergo a process of error and noise removal, which is referred to as **Data Cleaning**.

While the processes of data prediction and normalization were effectively and efficiently carried out through Excel, for the data cleaning, the utilisation of more context-appropriate static tools was preferred. Specifically, the decision was made to employ the **R Studio** software. R Studio is an exceptionally powerful and advantageous tool for data analysis, offering numerous benefits compared to Excel.

Indeed, this tool is designed for **advanced statistical analysis**, providing an extensive array of functions and libraries to execute intricate analyses and sophisticated statistical models. This is particularly valuable when studying variable correlations, developing regression models, or conducting predictive analyses.

The **quality of data visualizations** is another forte of R Studio. With a broad spectrum of graphical options and customizable features, it enables the creation of charts and graphs that render data easily interpretable and communicable.

Upon uploading the dataset to R Studio, the data-cleaning process began with an **exploratory data analysis**, examining **summary statistics** to obtain information on key descriptive statistics for each variable in the dataset, including mean, standard deviation, minimum and maximum values, and quartiles (25%, 50%, 75%). It is important to observe these statistics to identify missing values (NA) or outliers that could influence the analysis.

The subsequent sub-sections will provide an in-depth exploration of the comprehensive process employed for managing missing values and outliers.

Handling Missing Values

A deeper examination of the dataset, segmented by province prior to actual data cleaning, revealed significant data anomalies concerning the NUTS3 area of South Sardinia (ITG2H).

The in-depth analysis led to the decision to exclude this province from the study due to coherence constraints and extremely high data absence, as a proactive measure to avoid the *Garbage In, Garbage Out* (GIGO) effect of unreliable and flow-influenced data.

Through exploratory data analysis, it was observed that certain variables still exhibited a number of missing values (NA), even after the removal of the ITG2H-related sample. With 10.54% missing data in the dataset (78 out of 740 total observations), removal was deemed undesirable to prevent significant loss of variability. Hence, the use of imputation techniques to handle missing data was preferred over the straightforward removal of rows associated with NAs.

Imputation is a methodology that estimates missing values based on existing data and relationships among variables in the dataset. Various imputation techniques exist, with mean imputation being one of the commonly used methods, involving the replacement of missing values with the mean of the corresponding variable. While simple, this method may be sensitive to outliers. Consequently, **median imputation** was chosen, involving the replacement of missing values with the median of the variable. This approach is robust to outliers and could be a better choice if the variable distribution is non-symmetric, as in the case of the dataset utilized in this dissertation.

This decision to handle missing values preserves dataset completeness and avoids information loss, especially given the substantial number of variables considered in this study.

Handling outliers

Outliers are observations that deviate significantly from the bulk of the data. They can arise from distributions with heavy tails or simply from measurement errors. Such data can lead to a distorted format. This distortion alters the overall statistical distribution of the data in terms of mean, variance, etc., causing a disruption in the accuracy level of the model. Consequently, the management of outliers plays a pivotal role in constructing statistical models, as they can exert substantial effects on model outcomes.

Primarily, outliers can distort estimated parameters, compromising the reliability of analyses. Moreover, they might violate fundamental assumptions of statistical models, such as data normality and homoscedasticity, thus diminishing predictive accuracy. The presence of outliers can hinder the model's generalization to new data, making it challenging to formulate overarching conclusions. Model stability can also be jeopardized, yielding variable outcomes based on the presence or absence of anomalous data. Ultimately, outliers can distort result interpretation, leading to erroneous conclusions about variable relationships.

Nonetheless, an immediate blanket removal of outliers is not a suitable approach in general. Indeed, in cases where outliers correspond to numerical errors, their removal might be justified; otherwise, they could signify that the model being developed is not suitable to explain them. Therefore, a thorough analysis was necessary for each variable to substantiate the presence of outliers, aligning with the scope of this research.

Several outliers were eliminated when confident indications suggested they were measurement anomalies. However, most outliers proved to be reasonable consequences of extreme performance

variability among provinces, a fact well acknowledged in Italy.

Hence, the judicious handling of outliers through **variable transformations** has proven essential for crafting an accurate and meaningful statistical model. Particularly, employed transformations include *logarithmic transformations* for scenarios with significant data concentration near lower values approaching zero, coupled with sparse data widely dispersed at higher values. In such instances, not performing transformations would have posed issues with homoscedasticity. In other cases, unsuccessful attempts at logarithmic transformation led to the adoption of the power transformation, also known as the *Box-Cox transformation*. This statistical technique stabilizes variance and approximates data to a normal distribution. Its primary aim is to align data with fundamental assumptions of various statistical models, such as linear regression.

Although the variable transformations provided a valuable method for addressing a substantial number of outliers, further refinements proved to be necessary at a later stage. In fact, the persistence of some outliers had the potential to impede the model's significance. To address this concern, a decision was made to aggregate the outliers into a distinct subset within the original dataset, driven by specific considerations. The remaining observations associated with these outliers all demonstrated a correlation with distinct circumstances. Cities such as **Rome** and **Milan** exhibit inherent dissimilarities from other Italian provinces, rendering them exceptions that warrant differential treatment. Their inclusion within a model aimed at generalizability, as delineated by the established research questions, was deemed inadvisable.

Several factors contribute to this stance. Notably, Milan and Rome diverge markedly from the broader Italian landscape in dimensions, intricacy, resource concentration, and scale effects, among others. These attributes possess the potential to exert significant influence over the study's overall findings, potentially obfuscating the nuanced dynamics of remaining provinces. As a result, the feasibility of extrapolating outcomes universally across all provinces becomes a challenge, given the intricate interplay of these distinctive characteristics. With these considerations in mind, the model was constructed using the dataset, purposefully omitting these provinces characterized by outliers.

At this juncture, the dataset exhibits suitable summary characteristics for further progression. Refer to Table A.2 in Appendix A for additional details.

Finally, **Data validation** and **Reliability check** are two crucial aspects in the processing and analysis of secondary data. These processes aim to ensure data quality and accuracy, verifying that the data are precise, dependable, and representative of the studied phenomena while providing a robust foundation for the resulting conclusions and interpretations.

First and foremost, validation benefits from highly reliable and **recognized sources**, as highlighted in the preceding paragraph. As a precautionary measure, **cross-checks** were conducted to identify any errors or discrepancies in index computation. As explained, the need for synthetic indices not already available in finalized formats necessitated interventions for data reprocess-

ing and missing value estimation. The cross-checking performed by the authors through Excel allowed for the correction and prevention of various errors. The approach was **conservative** in nature; when faced with discrepancies not immediately or intuitively correctable, the respective observation was preferred to be removed from the dataset. While this led to a partial loss of variability, it ensured higher data reliability.

In certain instances, **post-validation** was also conducted by comparing multiple diverse sources and visually analyzing historical trends. Attention was devoted to ensuring measurement and magnitude coherence, considering historical regional and provincial tendencies.

The **final output** was a comprehensive, cleaned, and reliable database, ready to be utilized for constructing and testing the model.

By employing the statistical tools and techniques mentioned, the research seeks to provide objective and quantifiable insights into the research problem, allowing for the formulation of testable hypotheses related to indicators influencing the level of short-term regional economic resilience for Italian NUTS3 regions. Furthermore, this endeavour aims to draw **valid inferences** extending beyond specific time frames, regions and types of shocks.

5 | Model Validation

Having achieved a thorough understanding of the dependent and independent variables that compose the model for gauging short-term regional economic resilience and having built the cleaned and definitive database, the groundwork is now set for its **mathematical delineation**.

The model serves a twofold purpose, aptly addressing both the research questions encapsulated within the broader research objective. In the realm of statistics, the aim is therefore tied to the art of **inference**, namely the interest lies in understanding how each response variable is affected by the changing values of the independent variables.

This section focuses on elucidating the heart of this research, presenting the models for both the Resistance and Recovery phases of short-term resilience.

5.1. Model Specification

The essence of this thesis's exploration lies in the crafting of two parallel linear regression models, whose mathematical definition takes the following form:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_p X_{pi} + \epsilon_i$$

Where:

- Y_i is the **response variable** that symbolizes the short term regional economic resilience dimension for NUT3 area i;
- $X_{1i}, X_{2i}, \ldots, X_{ji}$ represent the chosen j **independent variables**, each reflecting diverse dimensions that shape the short term regional economic resilience;
- β_0 is the **intercept term**, representing the expected value of Y_i when all explanatory variables X_{ji} are null;
- $\beta_1, \beta_2, \ldots, \beta_j$ embody the **slope coefficients**, which elucidate the expected change in Y_i when the variable X_{ji} varies by one unit while holding all other explanatory variables constant;

- ϵ_i encapsulates the **irreducible error**, representing the intriguing element of uncertainty.

To construct the regression models within the R Studio environment, the power of the "`lm()`" function was harnessed. The `lm()` function forms the cornerstone of regression analysis, embracing the principles of **ordinary least squares** [1] (OLS) estimation to unveil the best-fitting line that encapsulates the interplay between independent and dependent variables.

The model for the Resistance phase was instantiated using the following formula within R Studio:

```
model_Resistance <- lm(RESISTANCE ~ Internal migration rate + Structural
    dependency ratio + Hospital emigration + Propensity to remote work
    + Education level + Seismic risk + Land consumption + Waste
    sorting diffusion + Patent intensity + Relative diversity index
    + Urbanization degree + Ultra-broadband penetration + Public transport
    speed + Administrative budget balance, data=data_cleaned)
```

Similarly, for the Recovery phase:

```
model_Recovery <- lm(RECOVERY ~ Internal migration rate + Structural
    dependency ratio + Hospital emigration + Propensity to remote work
    + Education level + Seismic risk + Land consumption + Waste
    sorting diffusion + Patent intensity + Relative diversity index
    + Urbanization degree + Ultra-broadband penetration + Public transport
    speed + Administrative budget balance, data=data_cleaned)
```

In both cases, the term "data_cleaned" refers to the dataset that has undergone the data processing and cleaning procedures detailed in Chapter 4.

5.1.1. Identification of Significant Variables

The process of identifying significant variables took place through progressive refinements of the model code itself. This process consists of two main phases:

- Collinearity Management;
- Variable Selection.

Collinearity Management

The model was constructed considering all the independent variables selected in the process described in this chapter. However, to enhance the model's reliability, a thorough check was conducted to ensure that the cleaned dataset did not exhibit any issues related to potential

[1] Using the method of ordinary least squares, the regression coefficients are identified by minimising the sum of the squares of the residuals, i.e. the Residual Sum of Squares (RSS).

correlations among the independent variables. Such correlations could lead to **collinearity** problems in the model, which could, in turn, compromise the validity of the results.

To perform this check, a **correlation matrix** was created among the independent variables. Specifically, the code was designed to highlight all potential positive or negative correlation relationships between variables. The graphical output is presented in Figure 5.1.

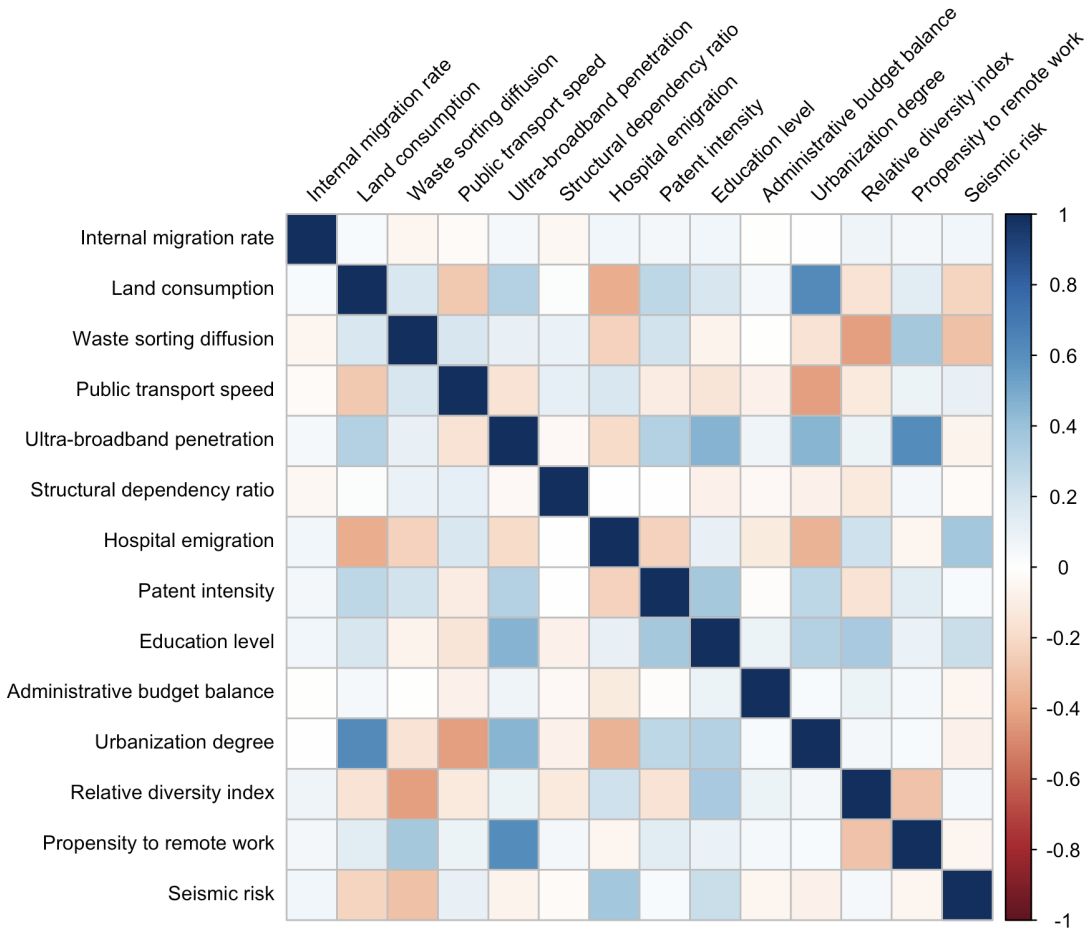

Figure 5.1: Correlation Matrix of the linear regression models' independent variables.

Subsequently, an absolute correlation threshold was chosen to define what is considered "problematic." Considering the complexity of the subject matter and the unique characteristics of the dataset used, the threshold was set at a relatively conservative value of 0.6. As a result, two potential collinearity risks were managed:

- the variable "Urbanization degree" exhibited a reasonably high correlation with the variable "Land consumption", leading to the exclusion of the latter from the model;
- the variable "Ultra-broadband penetration" showed a correlation with the variable "Propensity to remote work", which was consequently excluded from the model.

In both cases, the nature of the correlation might be attributed to the choice of metrics. Their removal represents a conservative approach aimed at maximizing the reliability of the achievable results.

Variable Selection

Consistent with the research questions, the objective of constructing this model for measuring short-term regional economic resilience is to identify, among the chosen variables, those that are truly indicative of short-term resilience in its Resistance and Recovery components. Consequently, the code for building the final model aimed to select the most relevant independent variables to include in each model, while eliminating those that might not significantly contribute to explaining the variability of their respective dependent variable.

This significant subset identification involves a **variable selection process**, executed through a Significance-Based Selection method, leveraging the summary feature of the `lm()` function in R Studio. For each incorporated independent variable, the summary displays its estimated coefficient, coefficient standard error, and the corresponding t-test statistic. The **t-test statistic** represents the significance test outcome, determining whether the coefficient significantly deviates from zero. The accompanying p-value quantifies the probability of attaining a coefficient as substantial as observed (or even more substantial in absolute value) under the assumption that the effect of the independent variable on the dependent variable is null.

Independent variables with p-values significantly lower (< 0.05) are deemed statistically significant. This suggests that the ascertained impact of the independent variable on the dependent one is unlikely to have occurred by chance. Such variables are likely to wield a tangible and significant influence on the dependent variable. It is common practice to retain these variables in the model, given their contribution to elucidating the variations within the dependent variable.

Conversely, independent variables with elevated p-values might lack a statistically significant impact on the dependent variable. When the p-value exceeds a notable threshold (0.05), it implies that the observed relationship between the independent and dependent variables could easily stem from random fluctuations. Consequently, these variables were gradually excluded from the model, one by one.

Ultimately, a post hoc validation was undertaken to verify the soundness of this manual selection through **stepwise regression**, an automated approach for refining regression models. This technique entails iteratively adding and potentially removing variables from a model, aiming to yield a more polished and comprehensible model.

In this linear regression analysis context, the stepwise selection was applied to both the Resistance and Recovery models using the R software platform. Initially, comprehensive models encompassing all conceivable explanatory variables were constructed. Subsequently, the R function `step()` was employed to orchestrate the stepwise selection.

For instance, in the context of the Resistance model, the following code snippet was executed:

```
stepwise_model_Resistance <- step(model_Resistance, direction = "both",
                                  scope = list(lower = ~1), test = "F")
```

Similarly, the Recovery model underwent the same stepwise treatment. In this case, `stepwise_model_Recovery` served as the container for the results of the stepwise selection process. The F-test was employed to assess the inclusion or exclusion of variables throughout the selection procedure. The `direction` parameter controlled the direction of the stepwise regression process: "forward" (adding variables), "backward" (removing variables), or "both" (both addition and removal). In this context, `direction = "both"` implies a comprehensive approach involving both the addition and removal of variables.

The `scope` parameter defined the range of potential candidate models that the stepwise procedure considered. The `list(lower = ~1)` syntax within the `scope` parameter does not prevent variable removal. Instead, it signifies that the initial model, from which the stepwise process initiates, includes only the intercept (constant). This means that the process can add variables to the model to improve data fitting, while the removal of variables from the intercept is precluded.

This process produced the same results as the manual selection based on statistical significance, thus confirming the **results** showed by Table 4.1.

Independent Variables	**Resistance_model**	**Recovery_model**
Internal migration rate	Signif. at p-value < 0.001	Signif. at p-value < 0.001
Waste sorting diffusion	-	-
Public transport speed	-	-
Ultra-broadband penetration	-	Signif. at p-value < 0.05
Structural dependency ratio	Signif. at p-value < 0.001	Signif. at p-value < 0.001
Hospital emigration	-	Signif. at p-value < 0.001
Patent intensity	-	Signif. at p-value < 0.05
Education level	-	-
Administrative budget balance	Signif. at p-value < 0.001	Signif. at p-value < 0.01
Urbanization degree	-	Signif. at p-value < 0.001
Relative diversity index	Signif. at p-value < 0.001	Signif. at p-value < 0.05
Seismic risk	-	Signif. at p-value < 0.05

Table 5.1: Variables Selection of the Regional Economic Resilience measurement models.

In conclusion, the scrutiny revealed that merely four out of the fourteen chosen resilience domains exhibited a discernibly significant impact on the Resistance response variable. Conversely, a noteworthy ten out of the fourteen demonstrated their significance in influencing the Recovery response variable. This divergence underscores the nuanced interplay between distinct factors and the multifaceted phases of regional economic resilience, enriching the understanding of its intricate dynamics.

5.2. Statistical Interpretation of Results

The final and definitive models for Resistance and Recovery were constructed utilizing the `lm()` function, following the procedure previously described. However, in this instance, the array of independent variables was confined to the subsets identified during the variable selection process.

In Table 5.2 and Table 5.3, the comprehensive summary of the `lm()` function for both models is shown.

The interpretation of model coefficients β_j unveils insights into the direction and magnitude of relationships between the discovered resilience indicators and the phases of regional economic resilience that are under analysis. A positive coefficient signifies a positive impact, while a negative coefficient implies a negative influence on resilience.

Table 5.2: Resistance Model Summary

Variable	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	0.59375	0.03652	16.257	< 2e-16 ***
Internal migration rate	0.18077	0.03271	5.526	4.9e-08 ***
Administrative budget balance	0.11070	0.03737	2.962	0.00318 **
Structural dependency ratio	-0.57156	0.03733	-15.312	< 2e-16 ***
Relative diversity index	0.11685	0.03002	3.892	0.00011 ***
Note: Significance codes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.				
Residual standard error: 0.1604 on 596 degrees of freedom				
Multiple R-squared: 0.3563, Adjusted R-squared: 0.352				
F-statistic: 82.47 on 4 and 596 DF, p-value: < 2.2e-16				

Table 5.3: Recovery Model Summary

Variable	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	0.28326	0.04917	5.761	1.35e-08 ***
Internal migration rate	0.53585	0.03262	16.429	< 2e-16 ***
Patent intensity	0.06318	0.02851	2.216	0.027098 *
Administrative budget balance	-0.10872	0.03737	-2.909	0.003760 **
Ultra-broadband penetration	0.08201	0.03750	2.187	0.029154 *
Structural dependency ratio	-0.15778	0.03639	-4.336	1.71e-05 ***
Hospital emigration	-0.14760	0.03576	-4.128	4.19e-05 ***
Urbanization degree	0.15676	0.03547	4.419	1.18e-05 ***
Relative diversity index	0.07995	0.03461	2.310	0.021218 *
Seismic risk	0.05719	0.02640	2.166	0.030704 *
Note: Significance codes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.				
Residual standard error: 0.1558 on 590 degrees of freedom				
Multiple R-squared: 0.4427, Adjusted R-squared: 0.4333				
F-statistic: 46.87 on 10 and 590 DF, p-value: < 2.2e-16				

In relation to Resistance, the coefficients of the variables consistently adhere to anticipated pre-modeling assumptions. Specifically, variables such as Internal migration rate, Administrative budget balance, and Relative diversity index exhibit positive coefficients. Conversely, the variable Structural dependency ratio bears a negative impact on resistance.

The findings veer slightly from initial expectations, particularly within the domain of Recovery. Within this context, a multitude of variables display coefficients in line with predictions. However, intriguingly, a subset of variables presents coefficients contrary to expectations, as indicated by the results.

For an in-depth exploration of these relationships and their accompanying explanatory context, the reader is encouraged to consult the dedicated chapter 6. Here, a comprehensive interpretation of variable relationships alongside their associated insights can be found.

5.3. Model Evaluation

The summary tools showcased in Table 5.2 and Table 5.3 offer a platform to apply established statistical methodologies for evaluating the reliability of the models' outcomes. A comprehensive scrutiny of the above will be undertaken in the ensuing sections.

5.3.1. Model Significance Measurement

Firstly, it is necessary to assess the overall statistical significance of the model. In the linear regression model, the interest lies in testing the *Null Hypothesis* $H_0 : \beta_j = 0$ against the *Alternative Hypothesis* $H_1 : \beta_j \neq 0$.

The Null Hypothesis states that the variable X_j does not have a significant influence on the variable Y in the corresponding short-term regional economic resilience dimension, implying no linear relationship between the two. Conversely, the Alternative Hypothesis suggests that the coefficient β_j associated with the independent variable X_j is not equal to zero, indicating a significant effect on the corresponding short-term regional economic resilience dimension.

Therefore, the observed parameter for interpreting a generic inference model and accepting or rejecting the Null Hypothesis is the *p-value* of the **F-test**. In the context of a linear regression model, the F-test statistic signifies the overall significance of the model. It evaluates whether the inclusion of independent variables collectively contributes significantly to explaining the variability of the dependent variable compared to a model without any independent variables.

A "low" p-value leads to the rejection of the Null Hypothesis and the conscious acknowledgement of a linear relationship between Resistance (Recovery) and the array of independent variables. In other words, the F-test allows us to understand that at least one predictor in the model is significant.

The F-statistics are significant for both the Resistance and Recovery models (p-value in both cases: $<$ 2.2e-16), indicating that at least one of the independent variables collectively has a significant impact on the dependent variable. Thus, the overall existence of these models is justified.

5.3.2. Model Goodness Measurement

It is also pertinent to estimate a measure of the model's capability to fit the data, through the definition of a ***goodness of fit*** index. In this case, the information provided by the summary of `lm()` is used again, specifically observing the R^2 **values**, which represent the proportion of variability in the dependent variable under analysis captured and explained by the specific model. It is computed as follows:

$$R^2 = \frac{ESS}{TSS} = 1 - \frac{RSS}{TSS}$$

Where:

- ESS represents the explained sum of squares;
- RSS represents the residual sum of squares;
- TSS represents the total sum of squares.

In essence, R^2 serves as a valuable tool to assess the model's ability to shed light on the quality of the model's fit to the observed data. A higher R^2 value indicates a better fit of the model to the data. A R^2 value close to 1 signifies a strong adaptation of the model to the data.

Specifically, the Resistance model has a lower R^2 value (0.3563) compared to the Recovery model (0.4427), indicating a better fit to the data. However, both R^2 values are relatively modest, implying the potential influence of additional yet unaccounted factors.

However, it is not deemed that these low values pose a problem compromising the validity of the model. The acceptability analysis of R^2 values depends on the specific research context and the expectations of the reference domain.

Indeed, the phenomena under scrutiny are complex, and inherently influenced by multiple factors that cannot be fully captured by a single model. For instance, among the selected factors, more statistically significant factors may have been excluded. Consequently, in such scenarios, naturally lower R^2 values can be obtained, indicating that the model explains only a portion of the variability.

Another important factor that reduces the goodness of fit of the models at hand is the inherent data variability. Even though a significant relationship exists between the variables, high data

variability can lead to modest R^2 values. This means that while the relationship is valid, the amount of variation explained by the model could be limited.

However, considering both the research questions, the goal is to identify the relevant factors, rather than precisely determining the angular slope between the response variables and the specific resilience factors. In this context, it is reasonable to believe that the R^2 results are still aligned with the expectations and objectives of the study.

5.3.3. Model Reliability

A **diagnostic check** was conducted on the residuals of each model to validate the assumptions of the linear regression model with the OLS method.

The diagnostic phase is particularly important concerning the verification of assumptions: failure to satisfy the model's assumptions could compromise the reliability of the results, even worse in a model as relatively un-robust to their violation as the one adopted by this thesis.

In this context, the main assumptions to be verified are the independence, normality and homoskedasticity of the model residuals. In brief, the **normality hypothes** guarantees that the residuals, hence the ϵ_i errors, are approximately normally distributed. **Homoskedasticity** indicates that the residual variance remains consistent across different levels of predictor variables, namely that the errors have constant variance. To test these assumptions, a graphical method was adopted involving the use of two R Studio plot functions, one for each model, whose main outputs are represented in Figure 5.2 and Figure 5.3.

In each plot, it is possible to observe two graphs:

1. **Residuals vs. Fitted**, which displays the residuals (ϵ_i) of the model relative to the predicted values. It is useful for identifying patterns in the residuals that could suggest violations of assumptions, such as non-homoskedasticity or non-linearity. For both the Resistance and Recovery models, within this framework, no distinct residual patterns can be identified. Therefore, the assumptions are considered satisfied in both cases.

2. **Normal Q-Q Plot**, which compares the quantiles of the residuals to those of a normal distribution. If the points approximately follow a straight line, the residuals can be considered approximately normally distributed. Again, for both models, this assumption can be considered satisfied.

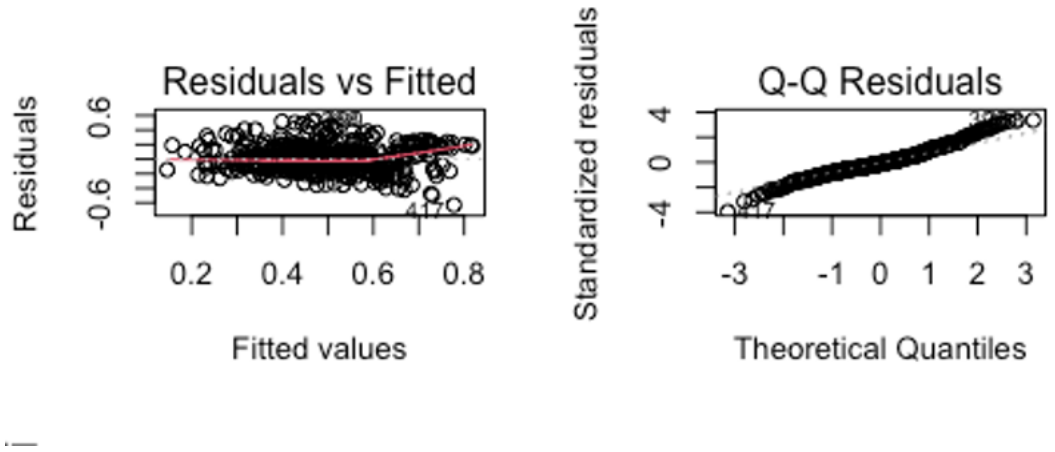

Figure 5.2: Diagnostic check on the Resistance Model

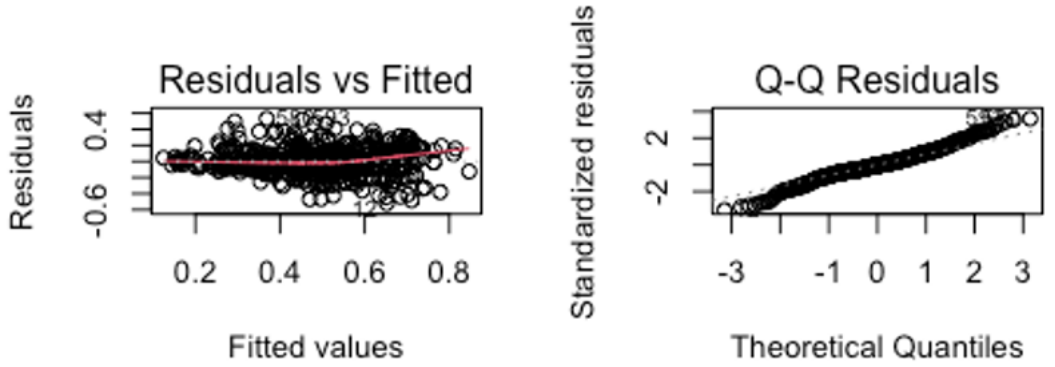

Figure 5.3: Diagnostic check on the Recovery Model

6 | Results & Findings

6.1. Overview of Short-term Resilience to COVID-19 in Italy

The initial most significant and important findings of this thesis stem from the computation of **Resistance** and **Recovery**. The calculated data provide a comprehensive insight into how different Italian provinces responded to the challenges posed by the COVID-19 pandemic.

Provinces such as Crotone, Sassari, and Siracusa exhibited a decrease in employment of approximately four times that of the country average, showing a high sensitivity to the Pandemic disruptions. Conversely, provinces like Ragusa and Frosinone demonstrated resistance well above the average, implying reduced sensitivity and greater stability in maintaining employment levels during the crisis. Transitioning to the Recovery index, the data reveal a **heterogeneous landscape**. Provinces like Brindisi, Lecce, and Benevento showcased particularly positive recovery performances, underscoring the success of their efforts. Others, like Sassari and Cremona, grappled with ongoing challenges in employment restoration, probably due to the inability to implement timely measures to curb and alleviate the spread of the virus.

Turning attention to the Recovery index in a broader sense, as shown in Figure 6.2, the provinces exhibiting more pronounced recovery appear to be concentrated in the **southern regions** of Italy. This phenomenon could stem from the fact that the onset of COVID-19 reached the southern areas with a delay compared to the northern regions, thus allowing the provinces in the South more time to restructure their assets in preparation for tackling the Pandemic. Consequently, these provinces, if not experiencing a milder shock (higher Resistance), at least managed to recuperate at a swifter pace (higher Recovery).

However, it is important to acknowledge that the emphasis on the South's superior recovery may be partially due to the way resilience is gauged, which primarily relies on alterations in employment patterns. In the Southern regions, where employment levels are typically lower and exhibit greater inflexibility, the impact of negative shocks can result comparatively less pronounced. In other words, when faced with adverse events, employment changes in the South tend to be less drastic. This relative stability in employment is a double-edged sword. While it may lead to higher resistance to economic downturns and, even more, to a more rapid recovery,

it does not necessarily signify a positive economic environment. This is because the same rigidity that limits the negative effects of shocks also hampers the region's ability to adapt and evolve in response to new technologies and techniques.

This aspect manifests clearly that relying solely on employment fluctuations as a measure of resilience may provide an incomplete and potentially misleading assessment of a region's overall economic health. In fact, while employment appears to be the most suitable resilience measure for capturing the key factors driving the short-term response of Italian provinces to the COVID-19 pandemic, it is not a comprehensive measure of economic health on its own. Even though its synthetic nature aligns well with the objectives of this thesis and provides valuable insights into the immediate dynamics at play, this very nature makes it imperative to supplement the analysis with additional metrics and indicators.

Shifting now the focus to the distribution of Resistance levels across Italy, represented in Figure 6.1, while it is evident that both the North and the South have provinces with varying levels of resilience, this analysis shows that there is no consistent pattern of one region consistently outperforming the other. This reaffirms that the Pandemic's impact on employment was not solely determined by geographical location and emphasizes once again the importance of identifying the specific local factors that drive regions' performances in front of shocks.

However, in northern provinces, the Resistance index tends to be more homogeneous compared to the southern regions. This likely reflects the fact that the outbreak began in the North, which had less time to prepare and diversify its response. However, while some provinces like Trieste and Parma exhibited both strong Resistance to the shock and a robust Recovery, leading to employment levels even surpassing pre-shock levels, others like Lecco and Treviso, despite good resistance, faced challenges in returning to pre-shock levels.

On the contrary, provinces in the South generally displayed a wider range of reactions, with notable resistance peaks in Sicily, where provinces like Enna, Ragusa, and Cagliari stood out. Interestingly, some southern provinces, including Foggia, Benevento, and Brindisi, displayed positive Recovery indices despite low Resistance, indicating successful efforts to reinstate employment.

These disparities, coupled with the varying extent of the COVID-19 virus impact across Italy as previously discussed, could originate from distinct strategies in handling the Pandemic, divergent economic frameworks, and variations in infrastructural capabilities. The resulting inhomogeneity underscores the complexity of Italy's response to the shock, revealing distinct patterns of Resistance and Recovery driven by regional governance, economic composition, healthcare infrastructure, and public compliance with measures. In essence, the Italian experience of the Pandemic illustrates a nuanced interplay between Resistance and Recovery, characterized by regional nuances and multifaceted influences.

In general, the overall trend indicates a **weak correlation** between Resistance and Recovery.

This implies that a province's susceptibility to the initial pandemic shock (Resistance) doesn't necessarily determine its capacity to bounce back and recover economically (Recovery).

However, provinces with specific economic structures might encounter particular impacts from the Pandemic. For instance, Piemonte, especially Torino and Vercelli, with a substantial presence in the manufacturing and automotive industries, faced a pronounced initial shock due to disruptions in global supply chains and this turned into low Resistance indices for them. Furthermore, their recovery process remained sluggish even after restrictions eased, due to their reliance on international trade which delayed the economic rebound. Likewise, provinces such as Venice, known for their heavy reliance on tourism, were substantially affected by the shock, showing reduced resilience, and were further adversely impacted by the severe closures, which in turn impeded their capacity to rebound. These instances exemplify how specific attributes and economic intricacies can play a role in shaping provinces' levels of Resistance and Recovery witnessed during the COVID-19 pandemic.

These initial observations propose that areas reliant on a more **static economy**, such as heavy industry, tend to exhibit weaker Resistance. Conversely, regions dependent on dynamic and often smaller-scale activities (except heavily impacted tourism) tend to display enhanced Resistance performance.

However, the weak correlation between Recovery and Resistance levels underscores the significance of **locally executed measures** within each province. This highlights that a comprehensive response at a broader administrative level (regions) that enables such overarching strategies needs to be integrated with tailored actions at a granular local level (within provinces), to address the distinct economic landscapes, infrastructural nuances, and existing status quo within each smaller administrative entity.

6.2. Interpreting Short-term Resilience Determinants

In this section, a critical evaluation of the models' results is conducted, delving into the significance and the role of each identified determinant of Resistance and Recovery.

Upon scrutinizing the outcomes of the two parallel linear regression models, a clear pattern emerged within the indicators that exerted a substantial influence on the targeted resilience dimensions serving as response variables. As a result, these indicators can be effectively categorized into two well-defined subgroups:

- those having an impact on both Resistance and Recovery;
- those singularly influencing the domain of Recovery.

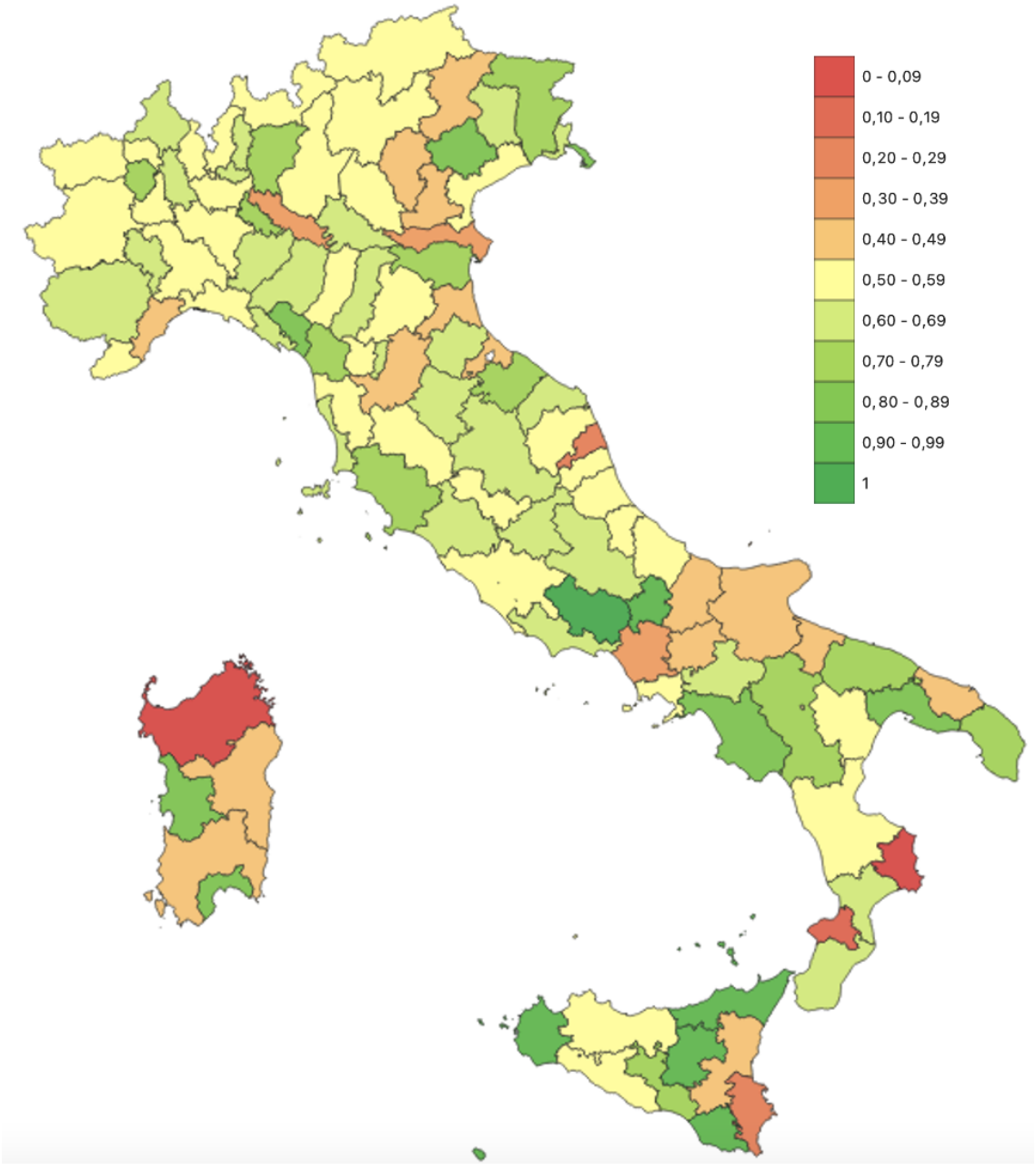

Figure 6.1: Map of the distribution of the Resistance index across NUTS3 areas in Italy.

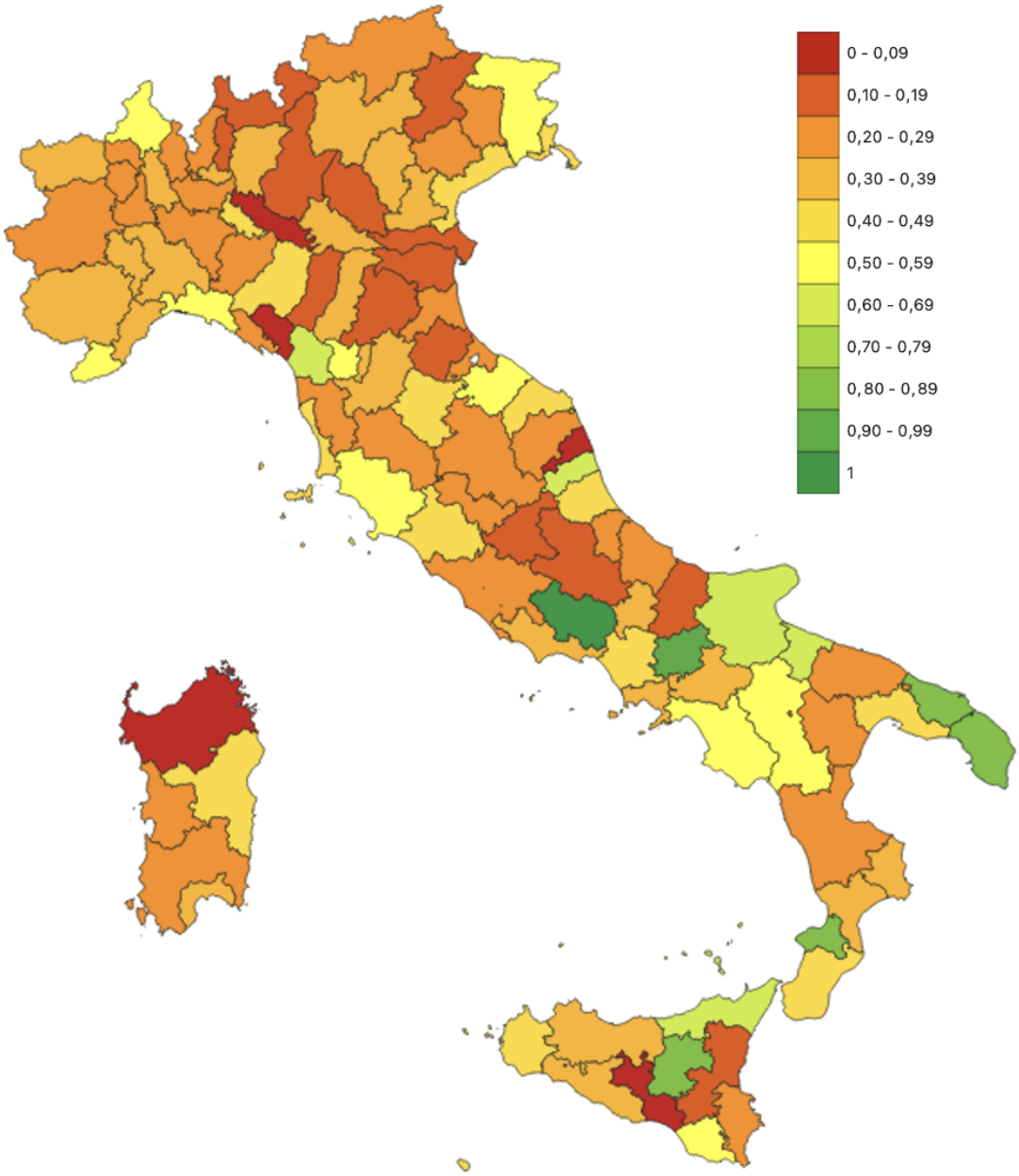

Figure 6.2: Map of the distribution of the Recovery index across NUTS3 areas in Italy.

An intriguing observation emerges from the analysis, as all the indicators contributing significantly to the Resistance dimension also appear within the set of indicators impacting Recovery. Interestingly, the reverse is not found to be true. This **divergence** prompts consideration of the dynamics at play. It is plausible that factors that hold pronounced importance in the immediate aftermath of the shock (thus determining high Resistance) continue to wield a lasting influence during the subsequent years of recovery. In contrast, during the Recovery phase, a new spectrum of indicators comes into play. This nuanced distinction may arise from the **temporal dimension**. Some factors that distinctly differentiate one geographical area from another might reveal their effects only when considered over a slightly broader time horizon. Such factors could be somewhat "muted" precisely at the moment of the shock's occurrence and its immediate aftermath, owing to their impact gaining prominence with time.

In other terms, factors pivotal for immediate resistance might coincide with those providing a foundation for the subsequent rebound process. The continuity in their significance underlines their sustained importance across both phases. However, the specificity of the Recovery phase introduces novel considerations, potentially driven by factors that operate with a delayed effect. These factors could encompass variables that demonstrate a cascading impact over time or those that gain traction as recovery strategies evolve and unfold.

A detailed examination of each factor demonstrating a noteworthy correlation with Italian short-term resilience follows, coupled with an endeavour to elucidate the intricate mechanisms through which they exert their influence.

6.2.1. Unveiling Dual Impacts: Determinants of Resistance and Recovery

Indicators concurrently influencing both Resistance and Recovery encompass:

- Internal migration rate;
- Relative diversity index;
- Administrative budget balance;
- Structural dependency ratio.

The first factor influencing both Resistance and Recovery is the province's **Internal migration rate**, reflecting the **population change** level within provinces. This factor exhibits a positive correlation with both dimensions: a relationship that is not unexpected given that higher migration rates often reflect a region's elevated dynamism. This dynamism acts as a magnet for diverse competencies, driving the attraction of skilled individuals. While this might not hold while considering total migration flow, as certain regions might attract foreign migrants due

to strategic location rather than regional dynamism, it is particularly meaningful when analyzing the internal migration rates, which encompasses movement between Italian provinces and regions.

A high internal migration rate indicates a province's distinct appeal, often due to a wide array of **employment** and/or **education opportunities**. Consequently, it becomes a destination for enterprising individuals motivated to realize their potential. Hence, elevated migration rates infuse the region with a rejuvenated workforce, enriched with new skilled and adaptable human capital. This enables the attractive province to face economic shocks with high *Resistance*, courtesy of its flexibility in adapting to market fluctuations. Simultaneously, the influx of new residents, driven by the pursuit of opportunities, injects renewed vitality into the province's economic engine.

Furthermore, this dynamic helps expedite post-disruption Recovery, playing a pivotal role in accelerating the restoration of economic vibrancy. The population fueled by entrepreneurial spirit is inherently attuned to evolving opportunities. This adaptability prompts a more agile resource reallocation, accelerating the restoration process. Resources are channelled into sectors poised for growth, aligning with emerging demands.

The positive relationship between migration rate and resilience is further bolstered by the fact that a negative migration rate, indicating more emigration than immigration, often signifies lower quality of life or limited economic prospects. This results in the outflow of skilled workers, depleting human capital and rendering the region more vulnerable to shocks while impairing its ability to recover.

In a broader context, the amalgamation of skills fostered by a high migration rate cultivates a more diversified economic landscape, mitigating over-reliance on specific sectors and thereby enhancing resilience. This very aspect underscores the significance of the macro-area **Community composition & development** concerning Italian resilience and paves the way for the introduction of the second relevant factor, related to the **Firm** macro-area: **Diversification** within a province.

In the context of *Resistance*, the **Relative diversity index** emerges as a pivotal cushion against the unforeseen shocks brought about by the pandemic. A higher Relative diversity index indicates a province with a mosaic-like economic structure, encompassing a broad spectrum of industries. This intricate economic network acts as a natural defence mechanism, safeguarding the province from vulnerabilities arising due to an overreliance on specific sectors. Thus, when confronted with the unparalleled disruptions triggered by the pandemic, an economy fortified by diversification possesses the adaptability necessary to absorb and recalibrate in response to these shocks. This diverse economic panorama becomes a protective shield, preserving economic equilibrium amidst the chaos and augmenting the province's ability to withstand adverse impacts, thus increasing its Resistance.

Transitioning into the domain of *Recovery*, the concept of diversification assumes a more profound role in shaping the trajectory of resurgence. A province enriched by economic diversity possesses a repertoire of sectors with varying degrees of resilience. These stronger industries serve as anchors for rapid recovery, often catalyzing the revival of other sectors that have been hit harder. This variegated economic palette offers a range of pathways for revitalization, empowering the province to harness multiple avenues to reconstruct its economic vitality.

The outcomes of this model thus unravel the ambiguity previously encountered in literature, demonstrating that concerning Italy's COVID-19 resilience, the beneficial effects of diversification have outweighed those of specialization. This outcome is likely intricately tied to the notion of **resource allocation**: a province with a wide range of industries is better capable of strategically channelling resources, directing them towards sectors showing the initial signs of renewal. This astute orchestration of resources amplifies the overall trajectory of recovery, ensuring resources are directed where they can yield optimal results.

Beyond resource allocation, economic diversification fosters an environment fertile for **innovation** and **entrepreneurial instinct**. With the coexistence of various industrial sectors, the **cross-fertilization** of ideas and practices becomes more feasible, enabling the transfer of insights from one sector to another and enabling the emergence of novel opportunities and business strategies in the short term.

The third factor that exhibits influence over both the Resistance and Recovery dimensions of Italian provinces in response to the COVID-19 pandemic is the financial condition of institutions, expressed as through the **Administrative budget balance** indicator, i.e. the administrative surplus (deficit) in relation to current revenue.

Its positive correlation with provinces' Resistance to shocks is quite intuitive. A favourable financial situation, as an indicator of **financial well-being**, enhances a province's ability to withstand both the Pandemic and other adversities in the short term. An administrative surplus, indicative of sound fiscal management, points to a province that has safeguarded its financial resources and cultivated a certain degree of fiscal resilience. This prudence boosts the province's capability to absorb and counteract disruptive events, thus boosting is *Resistance*. Indeed, it becomes a cushioning factor, enabling the province to sustain essential services, support social programs, and respond to economic fluctuations that arise as consequences of the shock.

However, surprisingly, when shifting the focus to the dimension of COVID-19 Recovery, the correlation takes a divergent trajectory, becoming negative. This implies that while a high administrative surplus lays a solid financial foundation for weathering shocks, it introduces complexities in the context of the subsequent phase of resilience. A positive administrative surplus in the immediate aftermath of the Pandemic's onset might signal a lower incentive to act swiftly during the Recovery phase and could lead to **suboptimal utilization** of the available funds. The presence of a surplus might encourage **complacency** or hinder the implementation

of essential stimulus measures. Consequently, provinces with ample financial resources might be less motivated to promptly allocate resources for revitalization efforts, thus slowing down the restoration process.

The dual nature of institutions' financial condition factor might reflect the intricate interplay between immediate stability and subsequent short-term dynamism. While a healthy financial state can provide a shield against shocks, it can also exert a counterproductive influence later in time. Recognizing this balance is crucial for crafting effective policies that leverage financial stability for immediate resilience while fostering adaptability for a rapid and robust resurgence in the short period. Nevertheless, it is worth noting that this outcome does not necessarily negate the potential for institutions' financial strength to confer greater long-term resilience. On the contrary, it is quite likely that having financial surpluses can help mitigate the effects of a shock over time. The observed negative correlation may simply stem from an initial challenge in understanding how to efficiently allocate these resources in the short term and the time required for making such crucial decisions. Moreover, given that the analysis of institutions' role is relatively recent in the literature and remains inadequately explored, this finding introduces a novel question about the scope of its validity or whether it might stem from a potentially imprecise selection of indicators representing financial stability. Thus, a more comprehensive investigation into this aspect becomes imperative to uncover the underlying intricacies of this phenomenon.

Shifting the focus onto the significance of the **Structural dependency ratio** as a measure of **Social fragility**, the negative correlation between this indicator and Resistance can be attributed to the challenges posed by a higher proportion of non-working-age individuals within a population. When a province has a higher dependency ratio, meaning a higher percentage of children and elderly individuals not part of the workforce, several issues arise that impact the area's ability to withstand and adapt during disruptions, especially in the short term.

For instance, provinces with a higher dependency index often face heightened pressure on essential services, as a larger dependent population requires specialized care and resources, particularly in the healthcare sector. This intensifies the strain on **essential services** and diverts attention and resources from strategic measures, impeding the region's capacity to allocate its resources to address extraordinary situations. During the COVID-19 pandemic, where healthcare has been significantly affected and rendered vulnerable, this situation has further strained an already fatigued sector.

This results in extended delays in the Recovery phase: the prioritization of stabilizing vulnerable populations can postpone essential economic regeneration, thereby creating a **cycle of instability**.

Lastly, provinces characterized by a significant non-working-age population might find themselves increasingly reliant on external assistance and resources. This dependence on **external**

support can curtail their autonomy in shaping and implementing tailored resilience strategies in a short time. Thus, the negative correlation between the Structural dependency ratio and both Resistance and Recovery underscores the critical importance covered by the macro-area of **Community well-being** in shaping Italian resilience to COVID-19, highlighting the influence of demographic composition on an area's ability to bounce back and rejuvenate its economy in the aftermath of disruptions.

6.2.2. Nurturing Recovery: Unraveling Significant Determinants

Moving to those factors solely linked to Recovery, they are:

- Patents intensity;
- Ultra-broadband penetration;
- Hospital emigration;
- Urbanization degree;
- Seismic risk;
- Education level.

The first variable that exhibits a positive correlation with Recovery is the number of patents issued per million inhabitants, which serves as a representative measure of the level of **Innovation** within a region.

This phenomenon can be elucidated by the unprecedented nature of a crisis like the COVID-19 pandemic, which necessitated equally unprecedented measures for Recovery. This, in turn, compelled individuals and organizations to pioneer new tools, procedures, and approaches to accomplish tasks that were no longer feasible using conventional, established methods. The urgency to find **novel approaches** and construct **innovative tools** in a short period became the only viable avenue to address challenges that had been brought to a standstill by the Pandemic's effects.

A noteworthy instance is the rapid proliferation of online meetings as a solution to the constraints on in-person interactions during the Pandemic. While platforms such as Zoom, Webex, and Skype were in existence and had some pre-COVID-19 usage, their adoption reached an unparalleled scale and a completely renewed usage during the crisis. This widespread adoption signifies a substantial innovation in how tasks are executed. The persistence of these changes is evident even post-pandemic, as many companies have significantly reduced in-person work in favour of remote work, leading to considerable reductions in office space usage. This shift represents a new paradigm, expected to endure for the foreseeable future and potentially permanently to a certain extent.

The issuance of patents in various domains (measured by this indicator) serves as a strong signal of the innovation occurring in devising new procedures and tools tailored to the distinctive demands of each domain. This, in turn, becomes a crucial catalyst for a more effective and quicker post-shock restoration.

In this scenario as well, the model does not exhibit a direct correlation with *Resistance*. This outcome could have been anticipated since innovation necessitates time for development and implementation. Consequently, although it plays a paramount role in Recovery, its impact might not manifest swiftly enough to be observable in the context of Resistance.

The negative correlation between Recovery and the **Hospital emigration** of patients to other regions for medical treatment highlights the significance of considering the macro-area of **Service availability**, specifically the presence of **Health facilities** within provinces. Essentially, the lower the occurrence of hospital emigration, the more favourable the outcome of Recovery.

Indeed, emigration for medical purposes often indicates a relatively weaker healthcare system within a province. This, which is already concerning under normal circumstances, becomes of paramount importance during times of crisis, where healthcare infrastructures face pressures that hinder the delivery of efficient and timely care to patients. This was particularly evident during the COVID-19 pandemic, where **hospital overload** and stresses on resources and personnel led to prolonged hospital stays and subsequently delayed patient discharges. As a result, the virus containment was slower, overall healing was delayed, and the general pace of Recovery was compromised, due to the prerequisite of establishing secure health conditions.

This concept, vividly illustrated by COVID-19, extends to various crises. Seeking medical care in other regions during crises leads to **inefficiencies** and **resource losses**, including workdays and associated costs. While these inefficiencies might be less pronounced in scenarios other than a pandemic or a widespread health crisis, their persistence remains evident.

On the other hand, the empirical application of this thesis did not exhibit a clear correlation between Hospital emigration and Resistance.

A plausible explanation is related to the **uneven spread** of the virus across Italy. Initially, the virus had a greater impact on the northern regions, which generally have stronger healthcare systems. As a result, there was not a significant migration of patients to hospitals in other regions. Moreover, once the South started to be affected, the northern hospitals were already overwhelmed and, in addition, mobility was restricted. Therefore, the possibility of voluntarily moving to another region to access a better healthcare system was virtually non-existent.

In brief, in some parts of Italy, the virus was potent but met with a robust healthcare system, while in other areas, both the infection and the healthcare system were comparatively weaker. As a result, the overall level of Resistance does not show a strong correlation with this factor.

As foreseeable, the developed model robustly demonstrates a substantial correlation between

Recovery and **Connectivity & access to digital network**, measured by **Ultra-broadband penetration**.

This correlation arises from the fact that these networks serve as essential and **foundational infrastructures** to enable the development and amplification of numerous other factors. For example, if considering innovation, as discussed earlier, it is intricately linked to the presence of fast and reliable digital networks.

This reality became extraordinarily evident during the response to the COVID-19 pandemic, where the ability to adapt quickly and recover heavily relied on digital tools and solutions. Moreover, the transition to remote work regimes, digital communication platforms, and online collaboration tools was proportionate to the widespread availability and utilization of high-speed digital networks.

However, the significance of connectivity extends beyond facilitating remote work and virtual meetings. The seamless operation of various ordinary business processes relies on the accessibility of robust digital networks. Activities like transactions, communications, supply chain management, and data exchange seamlessly occur through these networks, collectively contributing to a more effective economic Recovery in the short time. Additionally, connectivity is essential for any collaborative work distributed across different locations. These networks constitute the backbone of efficient business operations, including activities like orders, payments, shipment monitoring, and more—all of which can be executed digitally and seamlessly through dedicated systems adopted by modern enterprises. Even end-user transactions, such as online banking and the growing realm of digital commerce, heavily depend on digital networks.

However, a direct correlation between connectivity and **Resistance** did not emerge from the results of this model. This can likely be attributed to the fact that a certain level of activity requiring connectivity was already in existence and utilized before the advent of COVID-19. The transition to a more extensive use of connected tools takes time, a luxury not afforded during the Resistance phase.

For example, broadband connections in Italy were somewhat limited before COVID-19, even in areas where the fibre-optic network was accessible (and it was not available universally). Furthermore, expanding network coverage and onboarding new users require on-site actions that were hindered by the limitations imposed by the pandemic. Finally, the widespread adoption of connected tools necessitates training and cultural acceptance of this technology's utilization. These factors have likely collectively contributed to connectivity not emerging as a significant element in COVID-19 Resistance even though it did emerge as a factor driving Recovery in the short term.

As previously discussed, the model also uncovers a direct correlation between **Agglomeration economies**, proxied with the province's Urbanization degree and Recovery within the context of the COVID-19 pandemic. However, it's intriguing to observe that there isn't a discernible

relationship between the Urbanization degree and Resistance in the same context.

The rationale behind the positive correlation with *Recovery* can be traced to the enhanced **connectivity** and **interaction** prevalent in more urbanized regions. These settings naturally facilitate the exchange of ideas, resources, and expertise – a quality that became paramount during the Pandemic. The concept of agglomeration, particularly in industries sharing common traits, has already been explored as a catalyst for collective growth. This interconnectivity and the consequent **knowledge sharing** played a pivotal role in generating innovative solutions to the challenges imposed by the pandemic.

Consequently, when the Recovery process commences within specific industrial sectors of an agglomerated region, its positive effects tend to diffuse more rapidly throughout the area. This scenario exemplifies what is termed here as "**rolling effect**" of Recovery. The resurgence of certain sectors within an agglomerated environment quickly permeates complementary individuals and businesses, subsequently rippling outward in concentric waves. This dynamic is especially pronounced in urban environments, where the reverberations of recovery swiftly permeate the community, triggering broader economic revitalization.

A similar mechanism is operative in areas intricately reliant on complex supply chains. Here, agglomeration streamlines the efficient **distribution** of essential components, bolstered by proximity and a surplus of resources and services. As production lines restart, the cycle effect propels recovery, spilling outward to amplify economic resurgence across the region. Notably, these processes tend to unfold at a more measured pace in rural locales.

However, the model suggests that this cascading effect is considerably diluted when it comes to the dimension of Resistance. This divergence can be attributed to the region being unexpectedly struck by the epidemic on an unprecedented scale and at an unparalleled pace. This abrupt impact disrupted the inherent inertia of various activities, which found themselves grappling with entirely novel situations and contexts. As a result, the rolling effect that later facilitated Recovery took time to initiate and was not prominent during the initial shock. This aspect echoes the debated notion in the literature that increased urbanization accentuates the province's structural and functional rigidity at the moment of shock. The economy requires a certain duration to recalibrate and stabilize, enabling the benefits of agglomeration to eventually outweigh this constraint.

Proceeding to a relationship that is more surprising and diverges from initial expectations, the focus will shift to the role of the **Seismic risk** indicator in shaping COVID-19 Recovery. Despite showing a less robust correlation than the other indicators, this factor warrants closer examination.

Even though the positive correlation between **Seismic risk** and the Recovery index might appear counterintuitive at first glance, a deeper analysis reveals that it could be attributed to several underlying factors. One possible explanation is linked to the **preparedness** of provinces

with higher values of horizontal ground acceleration. These provinces often invest in disaster preparedness and **response measures** and are characterized by infrastructures and health systems established to address unexpected disruptions' consequences in a more agile and organized way. These preparations can translate into a more robust and adaptable response to other types of crises, such as the COVID-19 pandemic, in the short term.

Furthermore, the experience in managing frequent seismic events could foster a culture of **evolution** and **dynamism** in these provinces and among the people living there, making them less susceptible to stress and concern during the onset of an extraordinary situation. Communities accustomed to managing and recovering from seismic events may exhibit similar qualities when faced with challenges posed by a pandemic, such as implementing containment measures, mobilizing resources and coordinating response efforts rapidly.

Additionally, regions with higher seismic risk might have a history of **collaboration** and **community engagement** in the face of adversity. The necessity of coming together and supporting one another during seismic events could influence the response to a pandemic scenario, promoting a collective effort to adhere to health guidelines, assist vulnerable populations, and share resources.

It is important to note that the positive correlation between seismic risk and COVID-19 Recovery does not imply a causal relationship. Instead, it reflects a convergence of factors that contribute to the overall resilience of these regions. However, considering that the correlation is comparatively weaker than that of other factors, conducting further research becomes essential to gain a comprehensive understanding of the intricate dynamics that underlie this correlation and to validate the preliminary insights.

In conclusion, the variables that have been found to be non-significant, and therefore not determinants of Resistance and Recovery, are those representative of **education level**, **waste sorting diffusion**, and **access of transportation network**. However, it is essential to emphasize that the lack of significance in the model does not necessarily imply these factors are irrelevant as potential drivers of resilience in broader terms. Instead, it indicates that, concerning the specific case of COVID-19 in Italy within a short-term context, these factors may not have directly exerted a discernible influence on employment fluctuations, and subsequently, on the Resistance and Recovery indices.

For example, in the case of **education level**, it is highly plausible that a higher percentage of educated individuals creates an environment more conducive to the development of effective strategies for responding to shocks. However, given the exceptional and unprecedented nature of the COVID-19 pandemic, the heightened development of response strategies associated with higher education may not have materialized within the relatively brief timeframe of the analysis.

Similarly, but with a different perspective, the **accessibility of the transportation network**, while undoubtedly representing a significant asset for an area's overall economic health, likely

had less impact in the immediate years following the onset of COVID-19, during which mobility and the overall use of the transportation network were compromised due to pandemic-related restrictions.

Nevertheless, it is crucial to recognize that these factors could still hold relevance in different contexts or at different points in time. Their potential significance may become more evident under varying circumstances or when assessing resilience in response to other types of shocks or challenges.

6.2.3. Empirical Examples: A Glimpse into Italian Provinces

To obtain a more engaging empirical perspective on the determinants affecting provinces, an exploration of these significant factors and their influence on Resistance and Recovery indices across four distinct Italian provinces has been undertaken. The selection of these provinces is guided by the aim to highlight extreme cases, offering a panoramic view of boundary scenarios that unveil the intricate interplay of these determinants at the province level.

Specifically, the following scenarios are examined:

1. low Resistance and Recovery indices;
2. low Resistance index but high Recovery index;
3. high Resistance index but low Recovery index;
4. high Resistance and Recovery indices.

Case 1: Sassari - Low Resistance, Low Recovery

The first case represents a scenario characterized by low short-term resilience, exemplified by the province of **Sassari** in Sardinia, exhibiting both low Resistance and low Recovery indices.

The year 2020 posed significant challenges to the overall labour market vitality in Sardinia. Notably, the rise in inactive individuals was relentless, with vulnerable groups such as women and youth bearing the brunt of the impact. Some regions were more severely affected than others, with provincial-level comparisons highlighting Sassari, potentially due to its heavy reliance on the **tourism** sector, displaying the bleakest data. Conversely, the crisis seemed to spare regions with strong **agricultural** sectors, such as the inland areas of Sardinia. In these areas, the negative percentage variations in hiring remained significantly lower than the regional average.

Furthermore, sectors requiring physical customer presence, such as hotels, restaurants, and artistic activities, experienced the most pronounced percentage declines in hiring. Meanwhile, the agriculture and fishing sector maintained its 2019 hiring levels, and two sectors even experienced growth: domestic services and financial services. The growth in the latter can be interpreted as

a response to the constraints of the crisis, with many households and businesses compelled to rely on credit to a greater extent than in the past.

Hence, the significance of the determinant concerning the **diversification** of the local economy becomes evident. The Pandemic's prolonged disruption to the tourism sector serves as a compelling case study highlighting the dangers of overreliance on a single industry. The COVID-19 pandemic wrought havoc on the tourism industry, not only in its initial year of outbreak but enduringly over time. Prolonged mobility restrictions profoundly impacted the livelihoods of regions like the province of Sassari, and this impact was starkly reflected in the levels of employment variation, as effectively captured by the computed indices. This underscores the necessity for local economies to embrace diversification strategies to enhance resilience in the face of unforeseen challenges, such as the extended mobility restrictions witnessed during the Pandemic. Sassari's experience vividly exemplifies the repercussions of sectoral polarization, reinforcing the importance of a balanced economic landscape.

However, the challenging situation in the province under examination allows to shed light also on the role of other determinants that contributed to these adverse short-term resilience outcomes.

For instance, the **seismic risk** seems to play a role. Sardinia is universally acknowledged, especially by the GNDT [1], as an area characterized by low seismicity. In accordance with the Ordinance of Prime Minister 3274 of 2003, which established new criteria for the seismic classification of Italian territory, the island is classified as Zone 4. Such a risk level can be considered moderate. From this study, as previously reported, seismic risk emerges as positively correlated with the ability to achieve rapid recovery, thus Sassari's low level of this indicator and corresponding low level of Recovery capability showcase this correlation.

Another determinant playing a significant role in the case of Sassari is the relatively low level of **urbanization degree**, which further depresses response performance to shocks. Sardinia, and the province of Sassari in particular, aligns with the broader trend of having a lower level of urbanization compared to other Italian regions. This translates into fewer employment opportunities, especially in sectors such as industry and services, potentially leading to migration to urban centres in search of employment. In this context, it is not surprising that the **internal migration rate** of Sassari exhibits a medium-low value. Analyzed over the five-year period from 2018 to 2022, it reaches its lowest point in the year of the shock, signifying a loss of human capital that diminishes both Resistance and Recovery.

Additionally, the low level of urbanization can impact negatively the accessibility of services. Less urbanized areas might have limited access to services like education, healthcare, public transportation, and even technology connectivity. In fact, the province recorded particularly low **ultra-broadband penetration** rates in the pre-COVID-19 period. While there is a slight improvement post-shock, it still poses significant constraints on short-term resilience of the

[1] Gruppo Nazionale per la Difesa dai Terremoti

province. Thus, this area requires further investment to increase connectivity and support remote working, to become able in the future to cope with shocks in a more effective way. Finally, it is even possible to observe further influences from the significant determinants, such as a limited inclination toward **innovation**, as indicated by the remarkably low patent intensity. A stronger inclination toward innovation could have laid crucial foundations for a more robust Recovery.

Case 2: Vibo Valentia - Low Resistance, High Recovery

The second case, characterized by a low Resistance but a high Recovery profile, finds a fitting example in the Calabrian province of **Vibo Valentia**. Vibo Valentia's experience is intriguing, as it showcases the initial struggle when confronted with the shock, resulting in a significant employment downturn. This setback occurred despite the province already grappling with employment levels below the national average. The substantial employment decline, occurring when the labour market was already near its bottom, underscores the province's remarkable vulnerability to the shock, which hit with unrelenting force.

Also in this instance, the outcomes seem to have been influenced by several determinants. The **high rate of emigration** to other areas presents a genuine issue. Vibo Valentia experienced highly negative internal migration rates, particularly in the period leading up to the shock and during the year of the shock itself, reaching their lowest point.

Moreover, another factor that played a strong role in the first approach to the crisis was the social fragility of the area. In fact, the **structural dependency ratio** deteriorated significantly in the post-shock period, exacerbating the province's challenges to adequately support its communities.

On the flip side, the province's Recovery prospects appear promising, precisely because new determinants come into play compared to those of the Resistance phase, for which the province has better values and which therefore allowed for better performances in the second phase. In particular, although not without its challenges, including a high hospital emigration rate, the province exhibits strong signs of Recovery. Concerning the **broadband connectivity**, this indicator experienced strikingly low levels before the onset of COVID-19 but showed substantial improvement in the post-pandemic years. Correspondingly, remote work, initially limited, experienced significant growth post-COVID. Moreover, the high level of the **relative diversity index**, reiterates once again the strong influence of this determinant. Complementing this overview is the analysis conducted by Confartigianato, which scrutinizes sector-specific data. What emerges is the remarkable resilience of the manufacturing and construction sectors in the years following the outbreak of the Pandemic. In contrast, there has been no recovery to pre-2019 levels in the service sector, primarily driven by a reduction in the number of workers in commerce, hotels, and restaurants. Therefore, despite the fact that this is an area with a strong tourist vocation, the possibility of relying on other sectors, not compromised by the current

crisis, has allowed Vibo Valentia to take the lead.

This case exemplifies the intricate interplay of resilience determinants, where initial vulnerabilities do not necessarily foretell an inability to rebound. Vibo Valentia's journey highlights the province's remarkable ability to recover in the face of adversity, shedding light on the dynamic nature of resilience in the context of complex socio-economic factors. However, further considerations need to be taken into account. Although Vibo Valentia has made significant strides in recovering employment levels compared to the pre-pandemic era, it still grapples with one of the highest unemployment rates in the country, particularly affecting the younger population. Moreover, even when employment opportunities arise, there is no guarantee that they are free from irregularities or off-the-books work. These observations underscore the urgency of studying more specific determinants related to the dynamics of job insecurity in contemporary Italian society.

Case 3: Lecco - High Resistance, Low Recovery

The province of **Lecco**, located in Lombardy, serves as an illustrative example of the third scenario witnessed in Italy amidst the COVID-19 pandemic. This case presents a compelling narrative, as it exhibited commendable resilience during the pandemic, reflected in a high Resistance Index, while facing considerable challenges in the subsequent Recovery phase.

The data has revealed a surprisingly positive employment situation in the province of Lecco in 2020, despite the ongoing Pandemic, which was raising alarming concerns, especially given the numerous cases in the Lombardy region. This province demonstrated robust resilience in its economic and employment systems, particularly within the manufacturing industry. In the fourth quarter of 2020, it recorded the region's best performance in terms of industrial production, despite the challenges posed by the emergency.
Nevertheless, this initial display of resilience did not stem from sound premises and, as a result, it did not establish a solid foundation for subsequent years sustainability. This left room for vulnerabilities in the immediate aftermath. Specifically, the critical deficiencies appear to lie in the realm of economic **diversification** within the province. Lecco exhibits a strong concentration of metalworking companies with an integrated supply chain, firmly interconnected and performing well in global markets. These companies serve as suppliers to prestigious brands, and medium-sized enterprises lead in specific market niches. Nevertheless, the disruption of global value chains tested post-pandemic global relationships and highlighted the vulnerabilities of an economy overly reliant on a relatively narrow range of sectors.

Hence, despite a notable inclination toward innovation and a high urbanization degree, accompanied by the advantages of industrial districts, the conditions in Lecco were unable to sustain the initial resilience features over time. Nonetheless, the values of the resilience determinants remain relatively promising, hinting at future recovery, albeit slowed by some shortcomings.

Case 4: Frosinone - High Resistance, High Recovery

Finally, the case of **Frosinone**, located in the Lazio region, with its high resilience and steady growth, represents a positive note in the Italian scenario.

What is surprising about this province, which is usually situated away from the national spotlight, is that it was one of the very few cases in which the employment level not only did not decrease during the Pandemic year compared to pre-2020 levels, but recorded significant percentage increases (Delta 2020-2019 of 4.02%). This upward trajectory continued during the subsequent Recovery phase, ultimately positioning the province with the highest value on the calculated index in this study.

The primary catalyst for this exceptional short-term resilience lies in the province's substantial economic **diversification**. While both the agricultural and manufacturing sectors experienced contractions, the tertiary sector displayed substantial growth. Notably, this surge in employment was largely driven by women, emphasizing the province's commitment to advancing gender equality. Moreover, given the proximity of Frosinone to Rome, it is conceivable that this increase in the employment level, and thus both in Resistance and Recovery, might have been partially driven by the delocalization of some activities from more densely populated areas of Rome, perceived as more dangerous during the pandemics, to nearby less densely populated areas which could nevertheless supply a similar level of services. In this context, Frosinone demonstrated its readiness to address increased demand and seized this as an opportunity for economic growth.

In addition, Frosinone has increasingly kept pace with the evolving demands for simplification, innovation, and digitization, which have been accelerated by the urgent requirements imposed by the COVID-19 pandemic. In 2021, following the introduction of the "Smart Agenda," an electronic agenda enabling online appointment bookings and providing citizens and businesses with updates on ongoing services and procedures, the province launched its dedicated app. This app is designed to offer citizens and tourists valuable information regarding local administration and the most intriguing cultural initiatives. Additionally, it allows users to geolocate themselves in relation to the various points of interest in the Province of Frosinone and calculate the quickest routes to reach them. This demonstrates the commitment to digitize and make both the Public Administration and all cultural and interesting aspects easily and widely accessible to everyone. It reflects a strong drive towards two of the areas that positively impact Italian resilience, namely **innovation** and **connectivity**. Frosinone's success story underscores the advantages of a diversified and innovative economic landscape, highlighting the province's adaptability and resilience in the face of unforeseen challenges. This case serves as a valuable illustration of how strategic diversification and inclusivity, together with digitalization, can yield favourable outcomes even during trying times.

6.3. Implications of the Resilience Model for Policy and Planning

It is patently evident that areas identified as significant allow for observations on what should be the primary targets of government interventions. Subsequent sections of this narrative will offer useful insights into each of these areas, providing an opportunity to examine the feasibility and evaluate possible short-term intervention strategies. Considering the complex nature of this topic, only preliminary reflections are advanced, serving as fertile ground for contemplation.

Population Change and **Social Fragility** are inherently interwoven areas, often manifesting a cause-and-effect relationship. Consequently, addressing these intertwined challenges demands a dual-pronged approach: mitigating social fragility while capturing the potential of immigration dynamics (and thus of population change). This calls for the formulation of strategic initiatives that leverage the benefits brought about by immigrants who opt to settle in the province, enhancing the number of workers in the province. This entails cultivating a local ecosystem of **employment opportunities** that not only bolster social fragility by reducing the *structural dependency index* but also attract and retain valuable talents. Simultaneously, this approach significantly mitigates the impetus for individuals to contemplate emigration, thus reducing the *brain drain*.

Expanding beyond the realm of job availability, a comprehensive strategy would encompass reinforcing security measures, bolstering healthcare infrastructure, and enhancing essential services. These holistic requirements have been fervently pursued by governments over the past several years, but unfortunately, the desired results have not been achieved. This effort is evident in the Organizational Regulation of the Ministry of Labor and Social Policies, effective since May 2017, wherein, among the competencies of the General Directorate, lies the "promotion and management of initiatives related to active policies and the involvement of relevant services in the employment insertion and reintegration activities of foreign workers" [2].

The lack of success in this endeavour is likely due to the fact that in many cases immigration is not yet widely accepted and seen as positive. Instead, it is often associated with higher criminality and poverty rates, thus perceived as a factor that increases social fragility rather than reducing it. This very aspect can be confirmed by the same Regulation mentioned before, which emphasizes the need for "coordinating policies for the social and occupational integration of immigrant foreigners and initiatives aimed at preventing and countering discrimination, xenophobia, and racism". Such actions would not be necessary or would be needed in different forms if the Italian culture had a different perspective on immigrants.

This fact serves as a warning sign, indicating that more should be done and invested in this area. This is further confirmed by the fact that, despite €19.85 billion of the PNRR, namely 10.34% of the total amount, being allocated to the "Inclusion and cohesion" mission, the section

pertaining to labour policies aimed at increasing the employment rate makes no mention of the role of immigrants in this context [62].

Agglomeration economies, as delineated by the model, emerge as instrumental in elevating Recovery. Hence, it is imperative to give special attention to nurturing and cultivating them. Luckily, industries recognize the advantages of being integral to such agglomerations and are likely to welcome initiatives that catalyze their establishment or enhancement. In particular, the primary objective for what concerns the Agglomeration economies and the **Innovation** domains, should centre around fostering the establishment of "**Poles of Excellence**" and nurturing their germination within industries in conjunction with university support (often the bastion of innovative knowledge) and active collaboration with researchers. Strategies aimed at invigorating this realm can be developed along three fundamental trajectories:

- Endowing **contributions** or **tax incentives** to expedite the maturation of urban areas undoubtedly stands as a robust impetus. These incentives could be targeted at industries, companies and even individuals already within these areas, thus promoting loyalty and attracting an abundance of skilled talent, ultimately reinvigorating the entire landscape.
- At the physical level, **geographical demarcations** could be designated to group specific industries. By encouraging companies to establish bases in these demarcated areas, with advantageous conditions for acquiring land or infrastructure, a symbiotic relationship could be inaugurated. This would open the way to substantial benefits for the regions and provinces that orchestrate such favourable conditions.
- On the digital frontier, the encouragement of the creation of a "**virtual agglomeration economy**" deserves consideration. This is an economy in which individuals and industries function as an agglomeration, despite geographical dispersion. With a robust infrastructural framework and seamless connectivity, this approach could facilitate the emergence of such economies more easily and potentially at a lower cost. However, operationalising the parameters of such an approach could pose challenges in itself.

The pursuit of these various approaches demands a process of refinement and consensus-building, grounded in the specific needs and the willingness of all stakeholders to participate. To pave the way in this direction, it becomes imperative to identify the sectors and places where innovation holds the utmost significance. This involves a fusion of industry-derived imperatives and those needs politically defined as strategic for the country as a whole.

Proper resources should then be allocated to spur this innovation, with the participation of experts from all involved areas. In particular, **industry experts** play a pivotal role in steering clear of fruitless studies and unused developments while academic ones, with their profound knowledge base, can bring a scientific and rigorous perspective to new areas of innovation. Moreover, the inclusion of experts with a political orientation ensures the consideration of the

selected strategic areas in the country's policy, even if their immediate economic viability is not apparent. That is, innovation areas should be properly defined to strike a balance between industry/economy-driven urgencies and strategic sectors poised to deliver practical impacts only in the distant future. Adequate resources from governmental allocations and corporate endowments should be channelled to fuel these investigations.

In this regard, one of the pillars of the PNRR pertains to social and territorial cohesion, encompassing objectives that highlight the aim of mitigating local, regional, and urban-rural disparities [62]. While the proposed actions, which focus on fortifying urban areas, might seem initially counterproductive to this goal and even accentuate the disparities between rural and urban regions, it is important to note that the intention behind these proposals and the embedded innovation, especially through the concept of creating virtual agglomeration economies, is precisely to extend the benefits of urbanization to areas where a physical urban agglomeration might not be feasible. This strategic approach is aimed at ultimately diminishing such disparities.

Nonetheless, it must be emphasized that the PNRR should place greater emphasis on the advantages brought by the presence of cities and the significance of achieving sustainable urbanization. This approach could help mitigate the ecological drawbacks and enhance the manifold benefits of urbanization.

An initial avenue for this attempt can be observed in investment measure 2.2, focused on "Integrated Urban Plans", which primarily aims to "reclaim urban spaces and existing areas to enhance the quality of life by promoting processes of social and entrepreneurial participation" [62]. These projects are geared towards restoring community identities through the promotion of social, cultural, and economic activities, with a specific focus on environmental aspects. However, this endeavour should be extended to encompass areas that are not currently classified as vulnerable territories, thereby ensuring a more comprehensive and inclusive approach to urban development.

Connectivity and access to digital networks serve as foundational prerequisites for all envisaged measures, a fact supported by the model's findings. Some good steps were taken in Italy, particularly post-COVID-19, with the widespread deployment of fibre-optic transport networks. However, a determined effort is necessary to extend this technological advancement to urban areas at large, while simultaneously laying the groundwork for nearly equitable (in speed/quality) digital access in rural areas through innovative technologies like 5G, satellite, or emerging alternatives. In this regard, cost emerges as a pivotal determinant, significantly influencing the adoption of these technologies. Initiatives could be directed toward subsidizing infrastructural development in economically less viable regions, alongside provisions to assist individuals with limited means for accessing digital networks. These actions will also be beneficial for boosting **Remote work opportunities**.

Similar objectives, along with the drive for innovation, are already integral to the PNRR within

the allocated 40.29 billion euros (21.05% of the total) designated for the second component of Mission 2: "Digitalisation, innovation, competitiveness, culture and tourism". Specifically, they are at the core of **Component 2: "Digitalization, Innovation, and Competitiveness in the Production System"**, which aims to facilitate digital transition and promote innovation in the production system by encouraging investments in advanced technologies, research, and innovation.

Of particular note, 6.71 billion euros are dedicated to investments in Ultra-Fast Networks (ultra-broadband and 5G) to align with the new European **Digital Compass** strategy, which sets the goal of ensuring 1 Gbps connectivity for all and full 5G coverage in populated areas by 2030 [62].

Consequently, despite the substantial costs discussed before, this aspect seems to be adequately considered in Italy's resource management. The country launched the National Ultra-Broadband Strategy in 2015, which has already mobilized over 12 billion euros and aims to achieve the European target by 2026, four years ahead of schedule.

A tangible result of this effort was observed during the Pandemic, as economic support was provided to families with school-age children lacking access to computers or tablets. This support ensured unhindered participation in remote learning, preventing the inadvertent marginalization of segments of the population from various communal engagements. This initiative is in line with the PNRR's objective of digitally covering public administrations, schools, healthcare facilities, and museums across the entire national territory to reduce the digital divide and expedite the spread of 5G throughout Italy [62].

Exploring the insights provided by the indicator on **Hospital emigration**, it becomes evident that this phenomenon is assuming a more pronounced and tangible issue within the Italian context. This reiterates what has already been underscored by the objectives of the PNRR in this domain. Specifically, the initial component of Mission 6 of the PNRR outlines a highly significant strategy for bolstering territorial healthcare assistance services. In particular, this strategy is aimed at improving service delivery, particularly concerning [62]:

- prevention and local assistance;
- inadequate integration between hospital services, territorial services and social services;
- prolonged waiting times for specific procedures;
- limited capacity to synergize strategies for responding to environmental, climatic, and health-related risks.

Such interventions need to be adequately funded and meticulously monitored to gain the potential to diminish hospital mobility across the peninsula and ultimately engender notable enhance-

ments in addressing **territorial disparities**, whose importance has been emphasized repeatedly. Consequently, the focus must substantially target the South, which is currently deficient in structures and services, to ensure not only localized but nationwide improvements. In fact, this approach would mitigate the overcrowding of recognized and renowned hospitals (mainly located in the North) and address the lack of trust elsewhere, breaking the cycle that fuels mobility toward more established facilities.

However, this does not imply indiscriminately creating more facilities; rather, it involves genuinely and tangibly enhancing existing ones. A reflective consideration could also be entertained that, contrary to earlier propositions, an expansive proliferation of healthcare facilities encounters economic barriers due to the absence of economies of scale. Moreover, the viability of maintaining specialized expertise in smaller establishments diminishes, hindering the accumulation of specialized knowledge and practical experience. Paradoxically, an excessive dispersal of hospitals could yield outcomes that run counter to those envisioned for agglomeration economies, resulting in adverse effects in the healthcare domain.

Hence, striking a balanced equilibrium between these two trajectories becomes imperative. This endeavour would entail ensuring universal access to healthcare facilities within reasonable timeframes while guaranteeing that each facility sustains the critical patient volume necessary to nurture medical personnel's expertise.

Lastly, this thesis has underscored the paramount significance of a **diversified economic structure**. Undeniably, Italy is renowned for harbouring an economy distinguished by a broad spectrum of industrial and commercial sectors. This economic diversification has been facilitated by a rich and intricate history, coupled with a strategically advantageous geographical positioning within Europe. The empirical study conducted has reiterated the importance of nurturing such diversity, in order to enhance adaptability to market changes. To foster economic diversification a pivotal initial step can be that of bolstering Small and Medium Enterprises (SMEs) and sustaining emerging sectors, often introducing innovative products and services. By providing resources, financing, and incentives to these enterprises, a wider range of industries can thrive. Likewise, embarking on Research and Development (R&D) initiatives through the establishment of research centres and innovation hubs serves to accelerate economic diversification. In this context as well, the funds from the PNRR present a valuable opportunity to bolster the economy of the southern regions, aiming to provide a boost to the nation as a whole, which undoubtedly would achieve more favourable outcomes if every constituent part were capable of progressing at the same pace.

7 | Conclusions

7.1. Summary of Findings

The concept of resilience, though intricate, has been dissected by precisely defining its dimensions for analysis and constructing a comprehensive dashboard of determinants of short-term resilience in its Resistance and Recovery phases.

Chapter 6 has highlighted the significant outcomes from the two parallel models, gleaning insights from the empirical exploration of Italy in response to the COVID-19 pandemic. This further section aims to succinctly summarize the key findings, providing a concise overview of the discoveries made throughout this dissertation.

Firstly, the **employment rate** within Italy's NUTS3 regions emerged as a potent data source. Upon reanalysis, it offered insightful glimpses into the regions' responses to the pandemic shock. The diverse impact of COVID-19 and its consequences across the Italian peninsula was mirrored in the ebb and flow of the labour market, encapsulating significant changes from a multifaceted perspective. The reinterpretation of employment data facilitated the creation of two robust indices representing the short-term components of resilience à la Martin, namely the Resistance and Recovery phases.

The **Resistance Index**, whose distribution across Italy has exhibited no discernible pattern in terms of distribution, exhibited a strong correlation with a subset of the selected indicators. The relationship can be concisely summarized in mathematical terms as follows:

$$\begin{aligned}\textbf{Resistance}_i = 0.59 &+ 0.18 \times \textbf{Internal migration rate}_i \\ &+ 0.11 \times \textbf{Administrative budget balance}_i \\ &- 0.57 \times \textbf{Structural dependency ratio}_i \\ &+ 0.11 \times \textbf{Relative diversity index}_i + \epsilon_i\end{aligned}$$

This underscores the significance of several aspects:

- the importance of revitalizing and heightening the appeal of regions to mitigate internal emigratory flow;

- the necessity of a facilitated and stable financial state for local institutions, which need to establish financial reserves stands as a means to mitigate vulnerabilities;
- the cultivation of a diversified and adaptable economy responsive to market shifts, while reducing dependency on specific susceptible industries;
- lastly, on a more profound level, the criticality of well-crafted policies to address social fragility and provide assistance to the most vulnerable.

Moving to **Recovery**, the research provided substantial evidence of its multidimensional nature. Computation of the Recovery Index, by neutralizing diverse area-specific impacts, facilitated a clear identification of factors driving the disparate reconstitution paths of Italian provinces. In mathematical terms, the relationship between the Recovery variable and the significant indicators can be briefly stated as follows:

$$\begin{aligned}\textbf{Recovery}_i = 0.28 &+ 0.54 \times \textbf{Internal migration rate}_i \\ &- 0.11 \times \textbf{Administrative budget balance}_i \\ &- 0.16 \times \textbf{Structural dependency ratio}_i \\ &+ 0.08 \times \textbf{Relative diversity index}_i \\ &+ 0.06 \times \textbf{Patent intensity}_i \\ &+ 0.08 \times \textbf{Ultra-broadband penetration}_i \\ &- 0.15 \times \textbf{Hospital emigration}_i \\ &+ 0.16 \times \textbf{Urbanization degree}_i \\ &+ 0.06 \times \textbf{Seismic risk}_i + \epsilon_i\end{aligned}$$

In this instance, the number of relevant factors increases while their impact on the response variable diminishes. Nevertheless, this observation underscores the enduring significance of those factors that play a pivotal role in bolstering resilience during the initial encounter with adverse circumstances. Subsequently, time no longer suppresses other dynamics that gradually begin to exert their influence in the years immediately subsequent to the initial shock. Hence, this underscores:

- the significance of innovativeness, which holds pivotal importance in a rapidly evolving global landscape;
- the critical need to accord proper prominence to connectivity in contemporary times to avoid being left behind;
- the relevance of a cohesive hospital and social care infrastructure that unifies the country rather than perpetuating division into two distinct *Italies*;

- the potency of urban node connections, alongside the imperative of ensuring that peripherical areas are not cut off;
- eventually, the consciousness that the recovery capability, thus resilience, derives strength from previous trials, particularly evident in regions that have confronted challenges such as the heightened risk associated with seismic activity.

Table 7.1 serves as a mnemonic aid for recalling the macro-areas and associated regions that held significance within the framework of quantitatively assessing regional economic resilience. Hence, it enables a terse response to **RQ1** - *"Which specific factors have played a pivotal role in shaping the diverse responses to the COVID-19 crisis across distinct provinces in Italy?"*.

Conversely, the answer to **RQ2** -*"Given these factors, what actionable insights can be derived to guide effective policy-making and strategic planning aimed at enhancing regional resilience?"* - is provided , as can be readily inferred, by the concise overview of intervention measures summarized above and deeply discussed in Chapter 6.

Dimensions	**Macro-areas**	**Areas**	**Indicators**
SOCIAL	Community well-being	Social fragility	Structural dependency ratio
	Community composition & development	Population change	Internal migration rate
	Service availability	Health facilities	Hospital emigration
ENVIRONMENTAL	Natural hazards	Seismic risk	Seismic risk
ECONOMIC	Firms	Innovation	Patent intensity
		Diversification	Relative diversity index
		Agglomeration economies	Urbanization degree
	Infrastructures	Connectivity & access to digital network	Ultra-broadband penetration
	Institutions	Financial condition	Administrative budget balance

Table 7.1: Final table of categorisation of indicators whose significance was demonstrated in the Resistance and/or in the Recovery model.

In essence, the concept of resilience emerges as an intricately woven and profoundly **multidisciplinary** notion. Despite a primary focus on economic facets, its essence necessitates a broader perspective - evident in the determinants that have proven to be significant.

However, results are particularly sensitive to the temporal scope under consideration. In fact, the choice of the field of focus on short-term resilience assumes a pivotal role in ascertaining the determinants that hold value as robust indicators. The pronounced variability between the immediate response phase and the subsequent one serves as a compelling testament to this fact. Within this context, it is plausible to state that the long-term phases of Re-organization and Renewal may exhibit distinct determinants.

Furthermore, it becomes evident that this multidisciplinary essence of resilience is not limited to its definition and measurement; it extends to encompass a broad spectrum of dimensions that resilience, in turn, exerts influence upon. The study concludes that resilience embodies not only the ability of a region to endure or rebound from shocks but also its capacity to pursue a trajectory of successful developmental growth, characterized by productive and equitable utilization of its human, physical and environmental resources. Thus, the identified indicators should be perceived not only as potent tools to monitor regions and implement preventive strategies to effectively navigate future shocks and disruptions, but also as sources of insight into the factors that genuinely influence the future evolution of an economic region, irrespective of the shocks it encounters. Moreover, these factors themselves are influenced by the evolutionary pathways they navigate. Consequently, it is imperative to acknowledge their interplay in shaping a virtuous cycle while remaining vigilant against the potential for this interplay to devolve instead into a detrimental loop, a vicious cycle that is arduous to break free from.

7.2. Summary of Contributions

Firstly, a significant contribution of this thesis lies in its endeavour to clarify the concept of resilience. Specifically, it offers a comprehensive assessment of the definitions of regional economic resilience found in the literature, including ecological, engineering, adaptive, and transformational resilience.

This effort goes beyond a mere review of definitions; it extends to the assertion that the concept of **equilibrium** should be discarded as a foundational measure of resilience. Economic systems are in a constant state of evolution, adapting to their contexts, which renders the recognition of a static equilibrium implausible. Consequently, the need to consider resilience as an **evolutionary process** has become apparent. While equilibrium remains a valuable tool for modelling and index construction, it is not the central pillar for defining regional economic resilience. Thus, validation has been granted to the most recent comprehensive definition attributed to Martin, which harmonizes with and encompasses all preceding definitions.

However, beyond the acknowledgement of this definition, this study takes the next step towards establishing a thorough procedure for identifying the short-term determinants of regional economic resilience. While Martin's definition is embraced as a theoretical starting point, the urgency for a conceptualization of the **dimensions of analysis** is emphasized. Clarity has been

achieved through:

- formulating a systematic definition of **shocks**, including their recognition and categorization (*resilience to what*);
- providing an overview of possible levels of **granularity** that can be adopted in the analysis, along with their respective advantages and disadvantages (*resilience of what*);
- creating guidelines for selecting an appropriate **temporal framework** for an effective measurement of the phenomenon (*resilience over what period*).

Subsequently, this work provides an interesting contribution in terms of analysis of the existing **literature**, unveiling its heterogeneities and proposing the identification of a common thread among the determinants of resilience adopted. In pursuit of this goal, a comprehensive **categorization of resilience indicators** used in a substantial number of empirical studies is presented. This categorization into *areas* and *macro-areas* of three *dimensions* of resilience - Social, Economic and Environmental dimensions - is envisioned as a valuable framework for future studies, serving as a resource to effectively comprehend and explore the multidisciplinarity of the resilience concept. In doing so, it tackles the complex task of harmonizing all dimensions while comprehending the intricate interplay and overlapping dynamics of various changes.

The culmination of these efforts is realized through the development of the **Resistance** and **Recovery measurement models**. While applied to the context of Italy dealing with the COVID-19 pandemic, the foundational evaluations for model construction can be extended to other cases with comparable analytical dimensions.

Finally, the exploration of the models' results has facilitated the investigation of **tangible policy implications**, identifying valuable drivers for the development and sustenance of short-term resilience among Italian provinces.

7.3. Limitations and Future Research Directions

It is of significant importance to acknowledge and disclose the principal **limitations** of this research, thereby opening avenues for future debates and investigations that may contribute to the advancement of this subject.

The main limitations of the empirical application primarily revolve around **data availability**, which emerged as a substantial challenge during the construction of the dataset. Obtaining the required information with the desired granularity from the aforementioned public sources mentioned in Chapter 4 proved to be an arduous task. Consequently, compromises were necessitated, leading to the incorporation of proxies in the analysis in lieu of more specific yet unavailable indicators. This could have led to the selection of suboptimal metrics, which may have slightly

affected the analysis. Therefore, studies with more precise determinants could lead to valuable complementarity of the results.

Another limitation fundamentally concerns the **sample size**. This also plays a significant role in terms of the results observed in the assessment of model accuracy: smaller samples have reduced statistical power to detect relationships, resulting in relatively lower values of *goodness of fit* (in this case, R^2).

Furthermore, the resource-intensive nature of the research and the data availability necessitated a **pre-modeling selection** of resilience areas. This resulted in an absence of comprehensive structural verification for the significance of all resilience areas, and respective indicators, cited in the literature review. The selection process, as detailed in the dedicated section, involved procedures **subject to the authors' discretion**. Furthermore, certain variables that were initially chosen for inclusion in the modelling were subsequently excluded due to collinearity issues (e.g., Propensity to remote work and Land consumption). Hence, further studies could encompass additional variables that lay beyond the scope of this research. In fact, it is paramount to acknowledge that R^2 values indicate a substantial portion of the variability of resilience remains unexplained. This implies the presence of unobserved factors beyond the current model's scope, exacerbated by the high level of complexity of the phenomenon under observation. In addition, the semi-cross-sectional nature of the data limited the ability to infer causality at this stage.

The selected temporal scope yielded interesting insights into short-term determinants, however, further studies with less circumscribed scopes and broader time horizons might uncover new interesting factors, capturing trends and intrinsic resilience characteristics of territories. In this regard, future studies are encouraged to investigate and formulate analogous models for the subsequent phases of resilience, namely **Re-orientation**, which pertains to the structural changes initiated in the region to adapt to the newly established economic conditions, and **Renewal**, focusing on the capacity to restore the pre-shock developmental trajectories or transition to new and more efficient paths. This approach facilitates a comprehensive examination from a **long-term standpoint**, which is beyond the scope of this dissertation.

Moreover, the choice of the NUT3 territorial analysis unit represents a well-balanced compromise between granularity and the reliability of available data. However, a study conducted at the **municipal** level in Italy is believed to possess the potential to depict the nation's heterogeneity in greater detail, thereby facilitating the development of more precise models capable of explicating a heightened degree of variability.

Lastly, considering the pronounced outliers observed in this study, like Rome and Milan in the case of Italy, it might be worthwhile to include them in the creation of similar models. The development of **dedicated models for outliers** may offer a valuable contribution to investigating resilience in intricate and distinctive contexts.

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A | Appendix A

Table A.1: List of quantitative papers on the measurement of resilience.

	Definition of resilience	**Type of shock**	**Territorial unit of analysis**	**Geographic areas of analysis**	**Temporal framework**
[8]	Adaptive & engineering & ecological	Great Recession	NUTS3	Spain	2002-2015
[18]	Adaptive	Great Recession	NUTS2	EU	2001-2011
[24]	Ecological	Recession	NUTS2	Italy	1890-2009
[35]	Engineering & ecological	Country-wide employment shocks	NUTS2	Italy	past four decades
[36]	Engineering & ecological	Economic shocks	NUTS2	Italy	1992 -2012
[38]	Not specified	Great Recession	15 two-digits NAICS sectors	U.S.	2007-2009
[39]	Not specified	Great Recession	Individuals	US	2005-2011
[40]	Adaptive	Great Recession	MSA [1]	US	2008-2014
[42]	Evolutionary	Great Recession	NUTS3	Germany	2008-2010
[47]	Adaptive	Great Recession	NUTS2	255 NUTS2 regions in the EU27	2008-2013
[49]	Adaptive	Recessions	LLS [2]	Italy	2007-08 & 2009-10
[52]	Ecological and Engineering	Recessionary shocks	NUTS1	12 UK regions	1971–2010

Continues in the following page

[1] Metropolitan Statistical Areas
[2] Local labor system

Table A.1 – continued from previous page

	Definition of resilience	Type of shock	Territorial unit of analysis	Geographic areas of analysis	Temporal framework
[54]	Not specified	Great Recession	NUTS3	EU	2008-2012
[60]	Not specified	Economic downturns	NUTS2	13 regions of Greece	2001-2008 & 2008-2013
[59]	Adaptive	Great Recession	NUTS2	268 regions in EU-28	2002-2013
[73]	Not specified	Economic shocks	MSA	361 MSA in US	1970-2007
[83]	Adaptive	Great Recession	LADs [3]	Great Britain	2004-2014
[86]	Adaptive	Recessions	NUTS3	Italy	1970-2011
[90]	Adaptive	Recessions	NUTS1	UK	1979-83 & 1990-1993 & 2008-2010
[95]	Not specified	Great Recession	NUTS3	Central and South	1999-2011
[99]	Not specified	Recessions	NUTS1	17 Western countries	1870-2007, excluding war-related years
[105]	Adaptive	Recessions	NUTS2	EU	2000-2015
[104]	Adaptive	Great Recession	NUTS2	EU13 & EU15	2000-2015
[114]	Adaptive	Economic shocks	NUTS2 & NUTS 3	ESPON 31 European countries	1990-2011
[117]	Adaptive (adaptive cycle model)	Recessions	NUTS2	city region of Cambridge and of Swansea	1960s-2000s

Continues in the following page

[3] Great Britain's Local Authority Districts

Table A.1 – continued from previous page

	Definition of resilience	Type of shock	Territorial unit of analysis	Geographic areas of analysis	Temporal framework
[122]	Adaptive	Great Recession	EU Balkan countries, non-EU Balkan countries and central EU countries	Eastern Europe	2007-2011
[31]	Adaptive	Hazard and global climate change	Not specified	Not specified	Not specified
[32]	Disaster resilience	Natural disasters	Counties	FEMA [4] Region IV	2000-2007
[84]	Engineering	Natural disasters	Urban system	General framework without empirical application	Not specified
[88]	Engineering	Natural disasters and climate change	Villages	Maitara Island	Values at the moment of the survey
[97]	Adaptive	Natural disaster	TL3 [5]	5 selected TL in Japan	1997-2014
[116]	Engineering	Natural disaster	Counties	Missisipi	pre 2005
[107]	Engineering	Political shock	327 regions called Kreisen	West-Germany	1987-1997
[110]	Ecological	Link between resilience and sustainability	NUTS2	EU	2000-2012

Continues in the following page

[4] U.S. Federal Emergency Management Agency
[5] Japanese prefectures

Table A.1 – continued from previous page

	Definition of resilience	Type of shock	Territorial unit of analysis	Geographic areas of analysis	Temporal framework
[10]	Not specified	Pandemic	Provinces (NUTS3) & Municipalities & LLS	Italy	Last year available value for each indicator ranging from 2004 to 2020
[13]	Adaptive	Technological crisis	366 MSA	US	From 1975 to 2002
[21]	Ecological	Economic shocks	NUTS2	EU (EU27 and EU15)	pre-crisis 1995-2007, crisis 2008-2015, recovery period 2016-2030

Table A.3: Resistance Index and Recovery Index values at NUTS3 level in Italy.

NUTS code	Resistance Index	Resistance Index Standardized	Recovery Index Standardized
ITC	1.08	0.57	0.28
ITC1	1.08	0.57	0.28
ITC12	1.28	0.53	0.29
ITC15	0.81	0.61	0.34
ITC16	0.79	0.62	0.33
ITC17	0.39	0.69	0.30
ITC18	1.48	0.50	0.38
ITC13	0.20	0.72	0.27
ITC14	0.68	0.64	0.50
ITC2	1.17	0.55	0.33
ITC20	1.17	0.55	0.33
ITC3	1.07	0.57	0.46

Continued on next page

Table A.3 – continued from previous page

NUTS_code	Resistance Index	Resistance Index Standardized	Recovery Index Standardized
ITC31	1.29	0.53	0.53
ITC32	1.57	0.48	0.39
ITC33	0.93	0.59	0.52
ITC34	0.76	0.62	0.28
ITC4	1.09	0.57	0.26
ITC41	1.45	0.50	0.20
ITC42	1.38	0.51	0.20
ITC44	1.33	0.52	0.14
ITC4C	1.28	0.53	0.27
ITC46	0.36	0.70	0.37
ITC47	1.23	0.54	0.17
ITC48	1.10	0.56	0.28
ITC4A	2.34	0.34	0.09
ITC4B	0.87	0.60	0.32
ITC43	0.37	0.69	0.11
ITC49	-0.03	0.76	0.41
ITC4D	0.65	0.64	0.34
ITH	1.04	0.57	0.27
ITH10	1.10	0.56	0.29
ITH20	1.11	0.56	0.31
ITH3	1.25	0.54	0.27
ITH31	1.16	0.55	0.11
ITH32	1.93	0.42	0.31
ITH33	1.62	0.47	0.16
ITH34	-0.36	0.82	0.26
ITH35	1.31	0.53	0.40
ITH36	1.89	0.42	0.31
ITH37	2.10	0.39	0.16
ITH4	0.08	0.75	0.42
ITH42	0.17	0.73	0.51
ITH43	0.47	0.68	0.42
ITH44	-0.76	0.89	0.43
ITH41	0.37	0.69	0.27
ITH5	1.05	0.57	0.24

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Table A.3 – continued from previous page

NUTS_code	Resistance Index	Resistance Index Standardized	Recovery Index Standardized
ITH51	0.66	0.64	0.20
ITH52	0.69	0.64	0.46
ITH53	1.24	0.54	0.14
ITH54	0.71	0.63	0.39
ITH55	1.21	0.54	0.17
ITH56	0.33	0.70	0.17
ITH57	1.82	0.44	0.23
ITH58	0.91	0.60	0.14
ITH59	1.83	0.43	0.20
ITI	0.93	0.59	0.34
ITI1	0.79	0.62	0.40
ITI11	-0.42	0.83	0.00
ITI12	-0.10	0.78	0.67
ITI13	1.27	0.53	0.54
ITI14	1.52	0.49	0.38
ITI16	0.52	0.67	0.47
ITI17	0.96	0.59	0.26
ITI18	0.45	0.68	0.43
ITI19	0.99	0.58	0.22
ITI1A	-0.19	0.79	0.52
ITI15	0.59	0.65	0.36
ITI2	0.85	0.61	0.27
ITI21	0.75	0.63	0.26
ITI22	1.19	0.55	0.28
ITI3	0.99	0.58	0.41
ITI31	0.21	0.72	0.52
ITI32	0.49	0.67	0.45
ITI33	1.40	0.51	0.28
ITI34	1.23	0.54	0.61
ITI35	2.80	0.26	0.07
ITI4	1.02	0.58	0.29
ITI41	0.37	0.69	0.46
ITI42	0.75	0.63	0.15
ITI43	1.32	0.52	0.22

Continued on next page

Table A.3 – continued from previous page

NUTS_code	Resistance Index	Resistance Index Standardized	Recovery Index Standardized
ITI44	0.57	0.66	0.33
ITI45	-1.36	1.00	1.00
ITF	0.97	0.59	0.40
ITF1	1.05	0.57	0.28
ITF11	0.64	0.65	0.19
ITF12	1.33	0.52	0.40
ITF13	1.09	0.57	0.29
ITF14	1.10	0.56	0.22
ITF2	1.08	0.57	0.22
ITF22	1.91	0.42	0.16
ITF21	-1.08	0.95	0.39
ITF3	1.08	0.57	0.43
ITF31	2.23	0.36	0.40
ITF32	1.82	0.44	0.93
ITF33	1.41	0.51	0.37
ITF34	0.83	0.61	0.32
ITF35	-0.71	0.89	0.53
ITF4	0.66	0.64	0.53
ITF46	1.84	0.43	0.66
ITF47	0.10	0.74	0.24
ITF43	-0.48	0.84	0.41
ITF44	2.00	0.40	0.85
ITF45	0.28	0.71	0.85
ITF48	1.91	0.42	0.61
ITF5	0.42	0.68	0.46
ITF51	-0.02	0.76	0.56
ITF52	1.20	0.55	0.27
ITF6	1.30	0.53	0.35
ITF61	1.18	0.55	0.24
ITF63	0.45	0.68	0.30
ITF65	0.55	0.66	0.43
ITF62	4.27	0.00	0.30
ITF64	3.69	0.10	0.82
ITG1	0.74	0.63	0.36

Continued on next page

Table A.3 – continued from previous page

NUTS_code	Resistance Index	Resistance Index Standardized	Recovery Index Standardized
ITG11	-0.81	0.90	0.49
ITG12	1.18	0.55	0.37
ITG13	-0.84	0.91	0.63
ITG14	1.16	0.55	0.33
ITG15	0.22	0.72	0.02
ITG16	-1.13	0.96	0.82
ITG17	1.69	0.46	0.15
ITG18	-0.97	0.93	0.51
ITG19	3.00	0.23	0.20
ITG2	1.59	0.48	0.26
ITG2D	3.97	0.05	0.06
ITG2E	1.64	0.47	0.46
ITG2F	-0.73	0.89	0.39
ITG2G	-0.44	0.84	0.24
ITG2H	1.91	0.42	0.26

Table A.2: Exploratory analysis of the dataset with descriptive summary statistics for each variable (including the mean, standard deviation, minimum and maximum values, and quartiles - 25%, 50%, 75%).

```
summary(data)
##  ID_observation     Resistance       Recovery         Int. migration r.
##  Length:740         Min.   :0.0000   Min.   :0.0000   Min.   :0.0000
##  Class :character   1st Qu.:0.5148   1st Qu.:0.2234   1st Qu.:0.3980
##  Mode  :character   Median :0.5878   Median :0.3235   Median :0.4411
##                     Mean   :0.5961   Mean   :0.3544   Mean   :0.4300
##                     3rd Qu.:0.6935   3rd Qu.:0.4508   3rd Qu.:0.4776
##                     Max.   :1.0000   Max.   :1.0000   Max.   :1.0000
##
##  Land consumption  Waste sorting diff.     P. transport speed
##  Min.   :0.00000   Min.   :0.0000          Min.   :0.0000
##  1st Qu.:0.08285   1st Qu.:0.3959          1st Qu.:0.3552
##  Median :0.13495   Median :0.5924          Median :0.4437
##  Mean   :0.17021   Mean   :0.5463          Mean   :0.4615
##  3rd Qu.:0.21386   3rd Qu.:0.7094          3rd Qu.:0.5807
##  Max.   :1.00000   Max.   :1.0000          Max.   :1.0000
##                                            NA's   :7
##  U-b penetration            Structural dep.ratio       Hospital emigration
##  Min.   :0.0000             Min.   :0.0000             Min.   :0.0000
##  1st Qu.:0.2969             1st Qu.:0.3891             1st Qu.:0.1747
##  Median :0.4307             Median :0.5080             Median :0.2771
##  Mean   :0.4306             Mean   :0.5258             Mean   :0.3294
##  3rd Qu.:0.5623             3rd Qu.:0.6605             3rd Qu.:0.4296
##  Max.   :1.0000             Max.   :0.9987             Max.   :1.0000
##
##  Patent intensity  Education level  Admin.budget balance  Seismic risk
##  Min.   :0.00000   Min.   :0.0000   Min.   :0.0000       Min.   :0.0000
##  1st Qu.:0.03532   1st Qu.:0.2000   1st Qu.:0.2874       1st Qu.:0.2278
##  Median :0.07169   Median :0.3176   Median :0.3502       Median :0.4913
##  Mean   :0.12652   Mean   :0.3374   Mean   :0.3807       Mean   :0.4629
##  3rd Qu.:0.15023   3rd Qu.:0.4379   3rd Qu.:0.4457       3rd Qu.:0.6888
##  Max.   :1.00000   Max.   :1.0000   Max.   :1.0000       Max.   :1.0000
##  NA's   :69

##  Urbanization deg.  R. diversity index       Propensity to remote work
##  Min.   :0.0000      Min.   :0.0000           Min.   :0.0000
##  1st Qu.:0.2904      1st Qu.:0.6474           1st Qu.:0.4741
##  Median :0.4666      Median :0.7590           Median :0.5891
##  Mean   :0.4523      Mean   :0.7179           Mean   :0.5822
##  3rd Qu.:0.5790      3rd Qu.:0.8226           3rd Qu.:0.7004
##  Max.   :1.0000      Max.   :1.0000           Max.   :1.0000
```

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Acknowledgements

The authors wish to express their gratitude to Professor Giovanni Azzone and Professor Marika Arena for their attention, availability and invaluable support throughout the development of this thesis.

A heartfelt appreciation is extended to Politecnico di Milano, the academic institution that has fostered their educational journey.

On a personal note, the authors would like to extend their gratitude to their families and friends. Their unwavering support throughout this path has been a source of strength, encouragement and inspiration.