Pre-Analysis Plan of "A survey-based Impact Evaluation of NRRP on Italian municipalities" *

Contents

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1 Introduction

The Pre-Analysis Plan, which is commonly referred to as PAP, consists of a document written within the framework of a research project, where the researchers declare in advance the object of the study and all the technical information related to, such as the data collection methodology, the outcome variables of interest and the construction method, the sampling techniques, the estimation approach and model specifications. It consists of a tool that is usually used in medical research but recently adopted also in social science, as it allows us to avoid, or rather limit, some practices connected with the conduct of the research, which are generally defined as *"fishing"* but also *"data mining"* or *"p-hacking"* (Ofosu and Posner, 2024; Brodeur et al., 2020).[1] The PAP, increasing the transparency of the research project, encourages researchers to minimize these practices by returning more rigorous and reliable results. Despite its undoubted benefits, it also presents elements that could severely constrain research activity.

Here, the Pre-Analysis Plan of an observational study in the field of economics is presented, that is the protocol related to the research project entitled *"A survey-based Impact Evaluation of NRRP on Italian municipalities"*. Since empirical evidence of protocols in the realm of this discipline is quite scanty, this PAP deserves attention. More specifically, as highlighted by Burlig (2018), the PAP is usually drawn up in the case of randomized control trials, which are quite rare in economics, as the majority of papers are observational, i.e. non-experimental. Unfortunately, this creates difficulties with the PAP approach. In fact, for the drafting of a pre-analysis plan to boost the credibility of the research work, researchers have to demonstrate that they have written the protocol before having access to the data. In general, for observational studies, which rely on data that is already available and frequently public, this is a clear limit. However, it may be credible even in the case of observational studies, as in the case in which researchers collect their own data and develop PAP based on upcoming data releases, or use data with restricted access. This is the case of the study examined in this paper. Indeed, the PAP developed in Section 3 specifically refers to a survey-based project, so that the research design and the data analysis methods have been declared before data collection to increase the transparency and credibility of the results.

This document is structured as follows. Section 2 provides an overview of the definition of the Pre-analysis plan, its application in medical sciences, and its recent diffusion also

[1] Fishing consists in reporting among all possible results, only those that are statistically significant, novel, convincing, or support theoretical assumptions. P-hacking includes various activities, such as strategically selecting covariates or restricting the sample, that the researcher does to obtain results with better p-values.

in social sciences, with a focus on its objectives and the positive and negative aspects of its use, as well as on its limits. Section 3 exposes the various parts of the Pre-Analysis Plan of the research project titled *"A survey-based Impact Evaluation of NRRP on Italian municipalities"*. In particular, it defines the objectives of the research, the hypotheses to be tested, the main outcome variables of interest, the survey design and the methods through which the data are collected as well as the econometric methodologies of analysis analysis that will be adopted.

2 Pre-Analysis Plan: the State of Art

2.1 Overall Framework

Research work can be defined as a staged journey and like any true journey, it needs a plan, which guides the traveler in the right direction. In theory, the Pre-Analysis Plan fulfills this purpose (Chuang and Wykstra, 2015).

Indeed, a Pre-Analysis Plan is a document, a sort of *"ex-ante report"*, within which the researchers define the design of their analysis in advance. It consists of a protocol, which is written before the beginning of the study and includes specific and technical information about the research project, such as the hypotheses, the sampling procedure and how the data will be collected, their source and how they will be handled, how the variables will be constructed and also any critical issues that may arise during the progress of the research (Chuang and Wykstra, 2015; Coffman and Niederle, 2015; Burlig, 2018; Ofosu and Posner, 2024). Table 1 illustrates, as an example, a short checklist of the main points that should be included in a PAP according to Olken (2015).

As reported by Casey et al. (2012) and Burlig (2018), the use of PAP is widespread in medical trials but less common in social sciences. According to Casey et al. (2012), Neumark (1999, 2001) was the first to apply PAP in economics, declaring in advance how he would use the data to analyze the impact of the new minimum wage law in the United States before the data were available. However, the application of the PAP, in particular for the preventive specification of the hypotheses, is widely increasing also in social sciences, especially in the case of analyses of randomized experiments in developing countries (Finkelstein et al., 2012; Banerjee et al., 2020).

In particular, there has been a sort of "credibility revolution" in economics, as Angrist and Pischke (2010) defined it, due to the new availability of data and new empirical models for estimating causal effects which have improved the rigor of economic empirical research (Burlig, 2018).

Table 1: What does the pap contain? A short checklist

Item	*Brief Description*
Primary outcome variable	The key variable of interest for the study. If multiple variables are to be examined, one should know how the multiple hypothesis testing will be done
Secondary outcome variable(s)	Additional variables of interest to be examined
Variable definitions	Precise variable definitions that specify how the raw data will be transformed into the actual variables to be used for the analysis
Inclusion/Exclusion rules	Rules for including or excluding observations and procedures for dealing with missing data
Statistical model specification	Specification of statistical models to be used, hypothesis and tests to be run
Covariates	List of any covariates to be included in analysis
Subgroup analysis	Description of any heterogeneity analysis to be performed on the data
Other issues	Other issues include data monitoring plans, stopping rules, and interim looks at the data

Source: Olken (2015), pp 65.

Despite this new approach in economic research, there is concern that certain long-standing practices in the research community may undermine these new benefits (Miguel et al., 2014; Christensen and Miguel, 2018). For instance, the practice known as publication bias[2], could garble results and hinder the replication of the analysis (Rosenthal et al., 1979; Franco et al., 2014; Humphreys et al., 2013; Brodeur et al., 2016; Ioannidis et al., 2017). In this sense, the PAP can indeed be a valid tool to limit, if not avoid, these controversial occurrences. It should prevent the so-called *"fishing"* also called *"data mining"* or *"p-hacking"*, which consists in reporting within the paper only the statistically significant results, ignoring those that contrast with the story that one would like to tell (Brodeur et al., 2020, 2024). PAP requires specifying in advance the econometric model, the outcome variables of interest, the covariates, the sampling methods, and any heterogeneity analyses.

Furthermore, it should also limit the practice whereby research hypotheses are formulated after having seen the data and not before, that is, the data are interpreted on the basis of the results of the analysis and not on the basis of the expectations deriving from the the-

[2] Publication bias consists in a distortion of research activity, according to which the statistical significance of the results influences the probability of publication (Brodeur et al., 2020).

oretical literature, i.e HARKing[3] (Okum and Bowers, 2024; Ofosu and Posner, 2024). It should increase the transparency of research since it tends to tie the hands of researchers in terms of their abilities to cherry-pick the hypotheses and which results are the most suitable to be included in a paper (for this reason the PAP is strongly recommended when there are multiple hypotheses to test within the same research project) or to choose other econometric specification or different data collection or cleaning procedure (Olken, 2015; Coffman and Niederle, 2015; Burlig, 2018; Ofosu and Posner, 2024).

2.2 Pros and Cons

The PAP's pros are well known. As shown above, the PAP is used with the primary objective of both increasing the level of transparency and consequently the credibility, of scientific research and limiting some critical points such as publication bias or specification search. This has obvious positive effects on readers, journal editors and reviewers, and policymakers, who can thus be more reassured that what they are reading does not represent the most convenient choice within a set of possible options.
Furthermore, the drafting of the PAP has positive effects on the overall quality of research. It requires researchers to think very carefully and meticulously about the hypotheses they want to test, reasoning about their meaning, compared to the theoretical models of reference (Casey et al., 2012).

In addition to the obvious benefits of drafting a PAP, there are also some negative aspects or rather costs. First of all, some limitations of the PAP concern its content. Some hypotheses will likely prove to be noteworthy at a later time, that is, they are not present in the initial draft, for example, due to a subsequent advancement of the literature on the subject. Especially in economics, moreover, the hypotheses to be tested are almost always more than one, which are often conditional on the realization of others and so on. This greatly complicates the preventive drafting of a well-defined work protocol (Casey et al., 2012; Olken, 2015). Furthermore, it is possible that the econometric model specification, which is another essential component of the PAP, is unable to adequately represent the data that only showed up ex-post. Defining the econometric model in a restrictive manner before examining the data can hinder the researcher's ability to learn. When the researchers observe and analyze the data, they may discover certain traits that they had not initially thought about. It is possible that the drafting of a PAP in advance inhibits the explanatory capacity of a research work. Furthermore, when researchers have access to a new dataset, they should extract as much information as they can from it,

[3] HARKing refers to the ex-post interpretation of results, rather than ex-ante on the basis of theoretical assumptions (Ofosu and Posner, 2024).

rather than limiting their analysis to just the predetermined research question (Olken, 2015; Coffman and Niederle, 2015).
There is also a question of both cognitive and temporal effort, required by the researcher in analytically mapping all the phases of the study. Very often he finds himself having to choose what to dedicate time and energy to, especially in situations of limited time Ofosu and Posner (2024). As already mentioned, it is likely that during the period of carrying out the research, the surrounding environment changes: new literature, new data, and political changes, require changes during the process. Essentially, researchers do not have the guarantee that the surrounding environment is stable and remains *"unchanged"* over time, compared to the moment in which the PAP has been written (Banerjee et al., 2020).

2.3 The Pre-Registration

Usually, once drafted, the PAP is filed in an archive. The idea is to secure the research protocol and avoid modifications or changes, as the pre-registration binds the conduct of research to follow specific steps before knowing the outcomes of the research itself. Although not mandatory, this commitment is usually achieved by inserting the research plan into a register maintained by an independent authority (Nosek et al., 2018).
In some cases, the trial registration is mandatory, for example under the U.S. law for research projects in medicine, and it is also required to publish in top medical journals (Casey et al., 2012; Burlig, 2018). Sometimes, the pre-registration is mandatory for publication in social sciences as well. For instance, the *Journal of Politics* requires PAP submission for all experimental studies, including surveys, from 2021. It is also a part of the refereeing process.[4]

The writing of the PAP and its registration with independent institutions should together pursue the aim of greater transparency of research activity. Nevertheless, according to (Brodeur et al., 2024), who analyzed the universe of randomized control trial studies published in 15 top journals, the pre-registration of research work usually does not include a detailed pre-analysis plan. This leads to the conclusion that the pre-registration of the study alone does not reduce p-hacking or publication bias, but when the pre-registration is accompanied by the PAP, the scientific credibility of the work increases, in terms of reduction of p-hacking and publication bias.

[4] There are many venues within which it is possible to register the research protocols. Among the most well-known there is the *American Economic Association RCT Registry* which allows registering the PAPs for randomized controlled trials (RCTs). The *Registry for International Development Impact Evaluations (RIDIE)*, which mainly refers to impact evaluation procedures for the development of low and middle-income countries, includes but it is not limited to randomized control trials.

2.4 To Sum Up: Does the PAP work?

As can be seen from the overview conducted in Section 2, the practice of writing the pre-analysis plan has lights and shadows. Despite some limitations, the primary goal of PAP is to avoid data mining and improve the transparency and credibility of research. Does it achieve this goal?

Pre-specifying the analysis undoubtedly has benefits, such as preventing data mining, specification searching and so on. So, the PAP could be seen as a *"tying one's hands"* practice (Casey et al., 2012).

The critical point lies in pre-specifying analytically and punctually the design of the study at every point. As regards the level of detail, Olken (2015) argues that especially in economics, specifying all logical relationships completely in advance is almost impossible, since it is usually not only a matter of highlighting the effect of a treatment on a reference variable but also of examining the underlying mechanisms and relationships. Furthermore, excluding some considerations from the paper because they are not pre-specified, the final results could be more transparent, but at the expense of a greater explanatory capacity (Olken, 2015). The researcher needs a certain level of flexibility to manage the complexity, even unexpected, of research work, even if the commitment inherent in a detailed PAP increases the research's rigor: it consists in what Casey et al. (2012) defines as the *"price tag"* of transparency. As Burlig (2018) specifies, the fact of having a predefined set of hypotheses to test does not prevent researchers from carrying out additional analyses, except for indicating which of them were pre-specified and which were not to guarantee the transparency of the work.

After all, it is nothing more than a question of balance: a sort of trade-off between the greater transparency and credibility of the research work associated with the PAP and the efforts required to produce it, as well as its practical limitations.

Nevertheless, the PAPs are not all the same. Ofosu and Posner (2024) investigate whether PAPs have been written and used in such a way as to make it possible to improve the quality of research. That is their content, level of quality and precision have been evaluated. According to the authors' findings, the PAPs, based on how they are currently written and used, fail to achieve the primary objective for which they were introduced and have spread.

In theory, greater transparency in research activity should lead to a greater likelihood of publication. Regarding the probability of publishing the research work, Ofosu and Posner (2020) note that papers that are accompanied by a PAP have an overall lower probability of being published. However, net of this, papers accompanied by PAPs are more likely to be published in top journals and be more cited. These dynamics could discourage the

adoption of PAPs by researchers and undermine the benefits that they could bring, albeit with some limitations, to the credibility and transparency of research.

3 The PAP for the project *"A survey-based Impact Evaluation of NRRP on Italian municipalities"*

3.1 Premise

The PAP that will be presented in the next sections refers to an observational study based on data that are not yet known as they will be collected through an ad-hoc survey. Thus, it is an appropriate case for the development of a PAP in the field of social science.
Moreover, even if this PAP has not undergone a pre-registration procedure by filling in a specific archive or a platform (see Section 2.3), the research team have declared, when presenting the project to the Italian Ministry of University, its commitment not only to the PAP drafting but also to its validation. The PAP that will be illustrated in the following pages has been disclosed, analyzed, and validated by an advisory board composed of institutional experts.

3.2 Background of the project

The National Recovery and Resilience Plan (hereafter, NRRP) is the instrument based on the Next Generation Europe funds and other complementary initiatives to support the economic recovery of the entire EU after the COVID-19 pandemic.

Italy is the country with the largest allocation of NRRP funds received. The Italian government will take advantage of these funds to sustain the country's transformation, reducing the structural and territorial gap toward inclusive growth by offering services and infrastructures to improve the well-being of local communities.
As recommended by the European Commission, the Plan was structured around six main objectives: green and digital transition; employment and smart, sustainable, and inclusive growth; social and territorial cohesion; health protection and resilience; and strengthening human capital. Moreover, it aimed to attack three main critical issues of the Italian economy: gender gap; youth exclusion, and spatial economic disparities.

The Plan was approved in July 2021. The original version of the Plan was made up of a set of 190 interventions, of which 132 were investments and 58 reforms (Sacchi et al., 2023). At the end of 2023, Italy asked for a revision of the original NRPP, now including

Table 2: The NRRP's Missions and Components

Mission	ID	Components
M1	M1C1	Digitalization, innovation, and Security of the Public Administration
M1	M1C2	Digitalization, innovation, and competitiveness in the production system
M1	M1C3	Tourism and culture 4.0
M2	M2C1	Green Firms and Circular Economy
M2	M2C2	Energy Transition and Sustainable Local Mobility
M2	M2C3	Energy Efficiency and Building Requalification
M2	M2C4	Protection and Enhancement of the Territory and Water Resources
M3	M3C1	High Speed and Mantainance of the Road Network
M3	M3C2	Intermodality and integrated logistics
M4	M4C1	Enhancement of Teaching and the Right to Study
M4	M4C2	From research to firms
M5	M5C1	Labour Policies
M5	M5C2	Social infrastructures, families, communities and the third sector
M5	M5C3	Special territorial cohesion interventions
M6	M6C1	Proximity assistance and telemedicine
M6	M6C2	Innovation, research and digitalisation of healthcare
M7	M7C1	RePower EU

Source: Italia Domani, 2024.

also an additional mission (*RePower EU*).[5] Currently, as reported in "Italia Domani", the Italian official website for NRRP, the total amount of the plan is 194.4 billion euros, of which 122.6 billion euros is in the form of loans and 71.8 billion euros is in the form of grants (Italia Domani, 2024). In order to fund all the necessary investments for the NRRP strategy, Italy has added further national resources to the Plan through a National Complementary Fund amounting to a total of 30.6 billion euros for the years 2021 to 2026 (Italia Domani, 2024). The current structure of the NRRP is defined in Table 2.

The NRRP provides for different levels of government as implementing entities for the projects. According to UPB (2022), approximately 36 percent of the Plan's resources are entrusted to authorities other than the central government, such as Regions, Provinces, Municipalities, metropolitan cities or other local administrations. ANCI (2024) reports that the part of the NRPP that sees Municipalities and/or Metropolitan Cities among the implementing entities concerns 41 investments and sub-investments divided into 9

[5] The regulation on *RePower EU* came into force, which became necessary following the Russian-Ukrainian war and for this reason, a new mission was added, with aim of strengthening energy distribution networks, accelerate production from renewable sources and increase energy efficiency (Montella and Mostacci, 2024; ISTAT, 2024).

components. To these are added 4 investments from the Complementary Fund. The combination of these investments leads to an estimate of the total amount of resources amounting to approximately 40 billion euros. However, to date, only 26 billion euros of the approved projects have been financed with NRRP funds.[6]

The project "A survey-based Impact Evaluation of NRRP on Italian municipalities" investigates the impact of NRRP funds received by Italian municipalities. The focus is on municipalities since a large share of investment lines encompasses the direct participation of municipalities with a significant impact on territorial development and citizens' quality of life. In particular, they are administrators, when acting as implementing authorities of a project, of the distribution of NRRP funds for a large share of interventions within the territory and for the modernization of public administration.

3.2.1 The Italian Municipalities and the NRRP

In Italy, there are 7,900 municipalities.[7] Approximately, 1300 municipalities are located in the Autonomous regions (Sicily, Sardinia, Trentino-Alto Adige, Aosta Valley, and Friuli Venezia Giulia), while the remaining ones belong to the Ordinary regions.[8] As it can be seen from Table 3, Italy is characterized by the presence of small and very small municipalities, in fact about 90% of Italian municipalities have a population that does not exceed 15,000 inhabitants and about 56% does not exceed 3000. Moreover, over 40% of the Italian population lives in municipalities with fewer than 15000 inhabitants, and about 9,5% reside in municipalities with fewer than 3000 inhabitants.

Despite their varying sizes, all municipalities share universal responsibilities. They are primarily responsible for urban planning, local transport, waste management, and social services, regardless of their population or resources.

The preeminence of small municipalities means that municipal administrators are in direct contact with citizens, knowing their needs and requirements better. At the same time, however, the fact that municipalities are so small means that they may encounter some difficulties in managing the processes of modernization of public administration, services on the territory, etc.

[6] Authors'elaboration on data provided by IFEL. IFEL stands for the Institute for Finance and Local Economy (in Italian: Istituto per la Finanza e l'Economia Locale), a foundation established in 2006 by the National Association of Italian Municipalities (in Italian: Associazione Nazionale Comuni Italiani, ANCI). IFEL has the role of assisting Municipalities in matters of finance and local economy. Furthermore, it can be considered as a reference structure for the collection, processing and dissemination of data relating to taxes, as well as a research and training body, producing studies, analyzes, and proposals for regulatory innovation. For further information, please consult the website: `https://www.fondazioneifel.it`.

[7] The number refers to December 31, 2023.

[8] Autonomous regions have greater legislative power and fiscal autonomy, including the ability to collect certain taxes and allocate spending.

Table 3: Distribution of population in Italian municipalities

Municipalities' Population classes	Num. of Municipalities	% of Municipalities	Resident Population	% of Resident Population
0-3,000	4,451	56.31	5,552,831	9,41
3,001-5,000	1,082	13.69	4,211,262	7,13
5,001-15,000	1,643	20.79	14,082,361	23,86
15,001-30,000	423	5.35	8,691,263	14,72
30,001-50,000	165	2.09	6,342,956	10,75
$>$ 50,000	140	1.77	20,149,460	34,13
Total	7,904	100.00	59,030,133	100.00

Note: The population data refers to 2021 and is taken from "A misura di Comune" (ISTAT). The number of municipalities in Italy in 2021 was 7904.

This uniform distribution of duties poses significant challenges, particularly for small and very small municipalities, which often lack the financial and administrative capacity to effectively manage these tasks. The arrival of NRRP funds should have helped municipalities improve some aspects, solve others, and implement projects aimed at increasing citizens' well-being and their quality of life.

The Italian municipalities that have presented, as implementing authorities, at least one project are 7,834 (out of a total of 7900 municipalities in Italy in year 2023), for a total of 54,978 projects.[9] The projects are included in 4 missions (see Table 4 and Figure 1) and 8 components (see Table 5). Table 6 and Table 7 illustrate projects distribution across Italy by size of inhabitants of the municipalities.

Table 4: Number of Projects per Mission

Mission	**Frequency**	**Percentage**
M1	40,870	74.34
M2	2,466	4.49
M4	5,009	9.11
M5	6,633	12.06
Total	54,978	100.00

Source: Authors'elaboration on IFEL's Data.

[9] The data on the projects financed by the NRRP which see municipalities as implementing entities were provided to us by IFEL.

Table 5: Number of Projects per Component

Mission	**Frequency**	**Percentage**
M1C1	40,015	72.78
M1C3	855	1.56
M2C1	1,039	1.89
M2C2	271	0.49
M2C3	190	0.35
M2C4	966	1.76
M4C1	5,009	9.11
M5C2	6,633	12.06
Total	54,978	100.00

Source: Authors'elaboration on IFEL's Data.

Table 6: Number of Projects per Mission for different population classes of the Municipality

	Number of inhabitants of the municipality						
Mission	0-3,000	3,001-5,000	5,001-15,000	15,001-30,000	30,001-50,000	>50,000	Total
M1	21,818	5,698	8,879	2,463	971	1,041	40,870
M2	970	339	494	147	94	422	2,466
M4	1,291	698	1,563	629	296	532	5,009
M5	1,112	313	618	1,386	1,008	2,196	6,633
Total	25,191	7,048	11,554	4,625	2,369	4,191	54,978

Source: Authors'elaboration on IFEL's Data.

Table 7: Number of Projects per Component for different population class of the Municipality

	Number of inhabitants of the municipality						
Component	0-3,000	3,001-5,000	5,001-15,000	15,001-30,000	30,001-50,000	>50,000	Total
M1C1	21,562	5,598	8,742	2,379	926	808	40,015
M1C3	256	100	137	84	45	233	855
M2C1	407	162	272	65	57	76	1,039
M2C2	1	0	0	0	11	259	271
M2C3	20	17	63	36	15	39	190
M2C4	542	160	159	46	11	48	966
M4C1	1,291	698	1,563	629	296	532	5,009
M5C2	1,112	313	618	1,386	1,008	2,196	6,633
Total	25,191	7,048	11,554	4,625	2,369	4,191	54,978

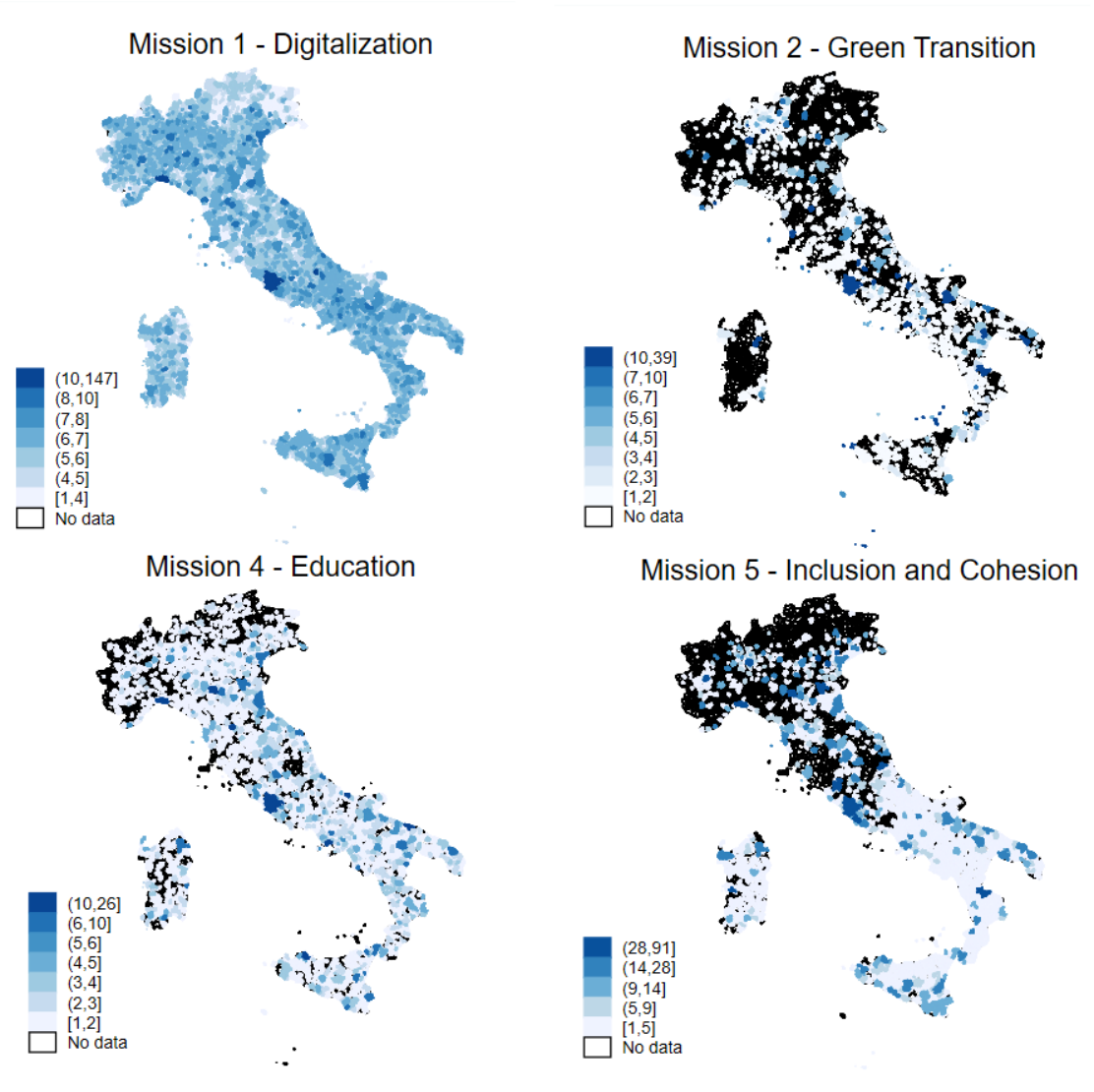
Source: Authors'elaboration on IFEL's Data.

3.3 Aims, rationale and objectives

The general objective of the project consists of four main goals. First, the project investigates whether the NRRP meets the goal of modernizing public administration, specifically focusing on digitization, simplification of bureaucracy, and strengthening the administrative capacity of municipalities. Second, the project evaluates whether the distribution of NRRP funds at the municipal level affects territorial development. It will assess whether the NRRP is effective in reducing inequalities and promoting inclusive growth by primarily increasing infrastructure investments, social innovations, and other initiatives inspired by the key targets of the NRRP, such as digitalization, economic transition, and enhanced resilience. Third, the project analyzes the impact of the NRRP on citizens' well-being by increasing the availability and access to goods and services, also through a new approach to service delivery that enhances the quality of life, empowers beneficiaries and communities, and fosters a more cohesive and inclusive society. Finally, the project assesses whether municipalities encounter difficulties and/or delays in the NRRP implementation, and more generally investigates critical aspects that need to be addressed.

These primary objectives enable us to evaluate the effectiveness of NRRP fund allocation in supporting the current and future development of territories, which was the original purpose of the funds. A positive impact on territorial development and human well-being reflects broad-based progress and an improved endowment of territories, which

Figure 1: Geographical Distribution of NRPP projects across Italian Municipalities by Mission



are essential conditions for addressing inequalities while enriching opportunities and laying the foundations for future prosperity. Moreover, an improved administrative capacity can generate long-lasting effects. For example, more efficient and effective municipalities can serve a larger number of residents and offer a higher quality of services in areas such as social interventions, thus ensuring a more equitable distribution of the benefits of growth, particularly for segments of the population that are often left behind (e.g., supporting female labor force participation through childcare services, improving access and use of facilities for disabled employees, addressing wage disparities and/or relative poverty, and so on).

Given the objectives outlined above, the impact of NRRP is assessed adopting an evidence-based impact evaluation approach. This method requires the consutruction of a counterfactual. However, real outcome data are not yet available. Therefore, a survey is conducted to gather information from municipalities regarding both the expected impacts and the projected counterfactual. The methodology follows the framework proposed by Aucejo et al. (2020), which adopts reported expectations as a stand-in for actual outcomes when real data is unavailable. A detailed description of this methodology can be found in Section 3.5.2.

This approach, on the one hand, allows us to estimate the expected impacts based on the financed projects as of now. On the other hand, it can serve as a guide for the counterfactual analysis once the real data becomes available, as it provides insights into how to collect the necessary data and suggests the indicators to be used for the evaluation.

3.4 Study Design

3.4.1 Research Hypotheses

Given the aforementioned general objective of the research, the specific operational hypotheses' system to be tested through the causal chain reported below (H1-H4) concerns the impact of the NRRP funds at the municipal level as follows:

H1. The NRRP has intensified, directly or indirectly, the digitalization and modernization process of Italian public administration,

H2. The NRRP has fueled local and regional development,

H3. The NRRP has increased, directly or indirectly, citizens' human well-being.

More specifically, it will assess the impact of NRRP funds on composite indicators of digitalization and modernization, territorial development, and human well-being of Italian

municipalities. Beside these primary outcomes, we assume the following (additional) outcome based on a supplementary hypothesis such as:

> H4. The implementation of NRRP encountered some technical and practical operational difficulties at the municipal level, because of multiple factors.

3.4.2 Population and Sampling

The research activity focused on Italian municipalities, having a reference population amounting to nearly 7900 municipalities. The research envisaged an optimal sample size amounting to 150 municipalities representative of different socio-demographic and territorial characteristics typical of Italian local communities, which represents about 2% of the whole population. The elementary unit of the survey is the individual municipality and one (or more) officer(s), i.e. a civil servant working in the municipal services, was asked to reply. No information on the willingness to answer the specific questionnaire was available ex-ante and the novelty of the survey prevented us from any kind of inference on the participation levels to the survey; sampling design is therefore exploratory and operates by sequential steps to be adaptive to vastly different scenarios, from a context of very low participation level to a broader level of participation. However, participation is not mandatory, even if it is elicited substantially with a continuous attentive reminder action. After specific training of operators and a pre-test phase based on voluntary municipal officers, the questionnaire is submitted to a complete list of contacts representing the entire population of municipalities. The list was provided by the National Statistical Service (SISTAN) and represents the responsible officers for official statistics in each municipality of the country. We pay particular attention to eliciting responses from:

1. all municipalities that are provinces cities;
2. municipalities defined in a low-level stratification sampling plan according to a few sampling criteria grounded on demographic characteristics (total population and age of citizens).

After the first (free) step collecting data from the municipalities voluntarily participating in the activity, we dedicated a second step to eliciting specific responses from new municipalities allowing us to reach the minimum sample size (n = 150) partitioned into a representative number of provincial head towns and other types of municipalities, stratified on the base of the declared demographic characteristics as mentioned above.

3.4.3 Data collection methods and survey design

As a primary data source, the project adopts an original survey that was submitted to all Italian municipalities. Answers are collected by online interviews with CAWI (Computer-Aided Web Interview) system (first wave) accompanied by telephone interviews and reminders and individual email reminders (second wave). These activities are carried out by a TP's operational consultancy specializing in data collection and analysis. The survey collects information, qualitative and quantitative, on the municipalities' activity executed in the field of digitalization, enrichment of territorial endowments, and development and promotion of human well-being.

Table 8: Survey's Structure

Mission	Component	Quantitive questions
M1	M1C1	Cloud enablement and facilitation Citizen experience in public services (Number of accesses to the Municipality's institutional website) Adoption of PagoPA platform services Adoption of App IO platform services Adoption of national digital identity platforms (SPID, CIE) Municipal employees who participated in IT training
M1	M1C3	Interventions for improving accessibility to public buildings and infrastructures (removal of physical and/or cognitive barriers) including museums, libraries, places of culture
M2	M2C1	Incidence of waste sorting on total waste
M2	M2C2	MwH produced through renewable sources with funds registered in the municipal budget (energy communities, self-consumers of renewables, etc.)
M2	M2C3	Primary energy consumption of school buildings in MWh
M2	M2C4	Square kilometers of Municipal Land classified as *at high* hydro-geological risk
M4	M4C1	Authorized places in nursery schools Total square meters of municipal school gyms Total square meters of municipal school canteens
M5	M5C2	Number of sports facilities built or regenerated

In more detail, it collects data about the municipalities in terms of digitalization of public services, investments in the territory i.e. level of separate waste collection, renewable energy, and energy efficiency; tourism and culture and social inclusion i.e. places available in nursery schools or canteens, green areas and parks. For a complete list of quantitative of the survey questions, see Table 8.[10]

Information is requested on the (actual and expected) levels of these quantities in the year before the start of NRRP (2021), in an ongoing year of NRRP (2023), and their future expectations at the end of NRRP (2026). The rationale is to collect data on what these outcomes/expectations would have been in the counterfactual state i.e. without NRRP funds.

In addition to asking about the outcome levels in the past, to date, and future expectations, a general opinion of the respondent is also asked on specific analysis dimensions including digitalization, territorial development, culture and tourism, and social inclusion, specifying whether these macro-themes would be improved, worsened or would be unchanged with or without the NRRP funds.

Furthermore, as a secondary data source, administrative data at the municipal level released by ISTAT – and possibly, other statistical sources of SISTAN – will also be used, to carry out a heterogeneity analysis, based on the different socio-demographic characteristics of each municipality analyzed. In particular, ISTAT data collections named "A Misura di Comune" will be used, which provide information at the municipal level on various research dimensions such as resident, female and non-native population, density, indicators of structural dependence and income levels. The majority of the above data were made available from 2014 to 2021.

3.5 Empirical Analysis

3.5.1 Main variables of interest

The outcomes, that is the main variables of interest, are indicators of digitalization and modernization, territorial development, and human well-being. These variables derive from the BES and SDG indicators associated with ISTAT and Italia domain to the targets of the various projects. In this case, they are computed as composite indicators, based on two original approaches proposed by Mariani et al. (2024) and by Polinesi et al. (2024).

Unlike traditional approaches for constructing composite indicators, which typically use

[10] The questionnaire, in Italian, is available at the institutional website of the project: `https://nrrpsurvey.econ.univpm.it/`.

simple power means without considering the variability of individual indicators, the penalized power mean method of Mariani et al. (2024) incorporates a penalization factor. This factor, directly linked to the horizontal variability among indicators, adjusts the power mean to reflect the balance across indicators. The penalization factor represents the loss of information that occurs when the indicator vector is approximated by its power mean. This approach assigns higher scores to units with greater balance among indicators when their power means are equal. Consequently, the resulting rankings are less affected by the choice of power mean order and are more accurate than those produced without penalization.

Specifically, let x_{ij} represent the value of indicator j for unit i, where $j = 1, \ldots, n$ and $i = 1, \ldots, m$. Define $\underline{x}_i$ as the vector of indicators for unit i (i.e., $\underline{x}_i = (x_{i1}, \ldots, x_{in})^\top$). The power mean of order p for unit i is given by:

$$M_{p,i} = \left(\frac{1}{n} \sum_{j=1}^{n} x_{ij}^{p} \right)^{\frac{1}{p}}, \quad i = 1, 2, \ldots, m.$$

The arithmetic mean, geometric mean, and harmonic mean are specific cases of $M_{p,i}$ for $p = 1$, $p \to 0$, and $p = -1$, respectively.

For $p > 0$ and for $i = 1, 2, \ldots, m$, the composite indicator $M_{p,i}$ can be seen as the solution to the following optimization problem:

$$\min_{c \in \mathbb{R}} F_p(c),$$

where $F_p(c)$ is the information loss function caused by replacing $h_p(\underline{x}_i)$ with $h_p(c)$, defined as:

$$F_p(c) = \frac{1}{n} \sum_{j=1}^{n} \left(h_p(x_{ij}) - h_p(c) \right)^2,$$

and $h_p(c)$ is a Box-Cox transformation of order p, defined by:

$$h_p(c) = \frac{c^p - 1}{p} \quad \text{for} \quad p \neq 0, \quad \text{and} \quad h_p(c) = \ln(c) \quad \text{for} \quad p = 0.$$

The solution to the optimization problem is the arithmetic mean, as $\frac{1}{n} \sum_{j=1}^{n} h_p(x_{i,j})$. In the transformed space defined by the Box-Cox transformation, the p-order generalized mean becomes the arithmetic mean of the transformed values.

The error or information loss from approximating $h_p(\underline{x}_i)$ by $h_p(M_{p,i}) = \frac{1}{n} \sum_{j=1}^{n} h_p(x_{i,j})$ in this transformed space is measured by the function $F_p(M_{p,i})$, and this error can be

expressed as the (biased) sample variance of the transformed values as follows:

$$F_p(M_{p,i}) = \frac{1}{n}\sum_{j=1}^{n}\left(h_p(x_{ij}) - \frac{1}{n}\sum_{j=1}^{n}h_p(x_{i,j})\right)^2, \quad i = 1, 2, \ldots, m.$$

that is the sample variance of $h_p(\underline{x}_i)$.
However, the sample variances $F_p(M_{p,i})$ relative to different unit i are different. To make the sample variances comparable across different units, the indicators for each unit are scaled by a specific criterion. This scaled indicator vector, $\underline{y}_i$, is given by:

$$\underline{y}_i = \frac{\underline{x}_i}{M_{p,i}}, \quad i = 1, 2, \ldots, m.$$

The error committed replacing $h_p(\underline{y}_i)$ with its mean $h_p(1) = 0$ can be rewritten in terms of the scaled vector $\underline{y}_i$ as follows:

$$L_{p,i} = \sum_{j=1}^{n}\left(h_p(y_{ij})\right)^2, \quad i = 1, 2, \ldots, m.$$

A larger value of $L_{p,i}$ indicates greater information loss due to using 0 rather than the full vector of sub-indicators $\underline{y}_i$.
We apply $L_{p,i}$ to penalize the power mean of order p. Specifically, for p, the penalized power mean of order p associated with the indicator vector $\underline{x}_i$ is defined as:

$$PM_{p,i} = M_{p,i} \cdot (1 \pm K\tilde{L}_{p,i}), \quad i = 1, 2, \ldots, m,$$

where $(1 \pm K\tilde{L}_{p,i})$ is the penalization factor, and $K > 0$ is a real constant.
The sign in the equation above depends on the context of the phenomenon. If increases in the indicator values imply positive changes in the phenomenon (positive polarity), we select $-$; otherwise (negative polarity), we select $+$.
The penalization factor decreases as the indicators become more balanced across units, capturing both central tendency and variability.
The penalized power mean includes the Mazziotta-Pareto Index (MPI) when $p = 1$.

The idea of Polinesi et al. (2024) is to associate to each indicator a set of probabilities, which are determined scaling the indicator with different goalposts. The goalposts reflect different expert opinions and/or min-max ranges in a panel data framework. The probabilities associated to each indicator are considered as the realization of a Beta random variable, whose unit-dependent parameters are estimated using the maximum likelihood

method. Moreover, the Beta random variable underlying the single indicator is used to measure the strength of the positive impact of the indicator on the phenomenon analyzed. The impact is Bernoulli random variable equal to 1 if the indicator has a positive impact, 0 if the indicator has no impact. Consequently, the impact indicators are independent and identically distributed Beta-Bernoulli random variables. These indicators are then used to define a composite index that combines both objective information (data) and subjective information (expert-suggested benchmarks).

Going into details, given the unit i the probabilities associated to the $j-$th indicator is computed as:

$$p^i_{j,r} = \frac{x_{ij} - m_{j,r}}{M_{j,r} - m_{j,r}},\ i = 1, 2, \ldots, N,\ j = 1, 2, \ldots, n,\ r = 1, 2, \ldots, R,$$

where R denotes the number of goalposts and $m_{j,r}$, $M_{j,r}$ represent the goalposts of the $j-$th indicator. For each unit i, the probabilities $p^i_{j,r}$ are assumed to be the realizations of the Beta random variable $\mathcal{P}^i$ with unit dependent parameters α_i and β_i. Therefore, the impact of the $j-th$ indicator variable is defined as follows:

$$X^i_j = \begin{cases} 1 & \text{with probability} \quad P^i_j, \\ 0 & \text{otherwise.} \end{cases}$$

From the assumptions on P^i_j, $j = 1, 2, \ldots, n$, it follows that the vector of the indicator impacts associated to the $i-$th unit $\underline{X}^i = (X^i_1, X^i_2, \ldots, X^i_m)$ is distributed as Beta Bernoulli random variable with parameters α_i, β_i.
The Beta Bernoulli Composite index (BBC for short) associated to the $i-$th unit is defined as follows:

$$I_i = \mu_i \left(1 - \frac{1}{\nu_i + 1}\right), \quad i = 1, 2, \ldots, m,$$

where μ_i and ν_i are given by

$$\mu_i = E(P^i) = \frac{\alpha_i}{\alpha_i + \beta_i}, \quad \nu_i + 1 = \alpha_i + \beta_i + 1, \quad i = 1, 2, \ldots, m,$$

Note that the BBC indicator is obtained penalizing the mean of the Beta-Bernoulli process by the correlation among the random Beta Bernoulli random variables $X^i_1, X^i_2, \ldots, X^i_m$.

The basic variables to construct the composite indicators are derived from the survey of Italian municipality as responses to the questionaire on the impact of NRRP. We calculate a composite indicator for each research question (H1, H2, H3).

3.5.2 Treatment effect analytic framework

The treatment is represented by the presentation of projects financed by NRRP programme. The data needed to estimate the impact of the program are collected through a survey. Impacts are estimated following Aucejo et al. (2020) which build on subjective expectations to evaluate decision-making under uncertainty. This approach consists in directly asking municipalities their expected outcomes in both states of the world, where one is the realized state and the other the counterfactual one. Let $O_i(\text{NRRP})$ be the potential outcome of municipality i associated with NRRP treatment. We are interested in the causal impact of NRRP on municipality's outcomes:

$$\Delta_i(O) = (O)_i(NRRP = 1) - (O)_i(NRRP = 0), \tag{1}$$

where the first term on the right-hand side is municipality's i outcome in the state of the world with participation in NRRP fund program, and the second term is municipality's i outcome in the state of the world with no participation to NRRP fund program.
This is a different approach compared to the traditional ones that deal with estimating counterfactual outcomes (Heckman and Vytlacil; Imbens and Rubin, 2015). In this case, through the survey defined in Table 8, the municipal government is asked for a sort of "belief": for example, the survey asks for the number of online services for the citizen activated by the municipality and those that would have been activated without the NRRP funds. So according to the proposed econometric approach, a municipality is directly asked for their expected outcomes in both states of the world.
The difference constitutes the effect of the treatment of the NRRP funds on the digitalization, in the case of the previous example, of the Italian municipalities. This approach is based on the assumption that the municipalities have solid expectations on the outcomes in the two cases - i.e. with and without NRRP funds.
This method is part of the literature that deals with analyzing expectations in decision-making processes under uncertainty. It has also been used by Arcidiacono et al. (2020) and Wiswall and Zafar (2021) to know the beliefs of college students to estimate ex-ante the treatment effect of college majors choices on work and family outcomes. Giustinelli and Shapiro (2024) used a similar approach to estimate ex-ante the effects of health on labor market outcomes.
This is exactly what will be done in this research work, since we are going to estimate ex-ante the impact of the NRRP on some outcomes, that is, before they are observed, given that the end of the program is scheduled for 2026.
Therefore, outcomes not yet achieved will be analyzed, the prediction of which is based

on the fact that the expectations of the municipalities are well-rooted. It is, therefore, a question of having indicators that provide a path on what is likely to be expected, since once the data are realized and no longer expected (after 2026) and therefore detached from the beliefs of the municipalities, it is possible to replicate the work, applying a "traditional" counterfactual estimation methodology, i.e. not based on beliefs, and compare it with the ex-ante expectations. Furthermore, this opens up interesting perspectives of analysis also on how the municipalities formulate their expectations and whether they are then confirmed or denied by reality.

We also control for the presence of a possible sample selection bias. The participation of municipalities in the survey is not mandatory and municipalities' participation in the survey may not be random. The probability of response is not identical for each municipality, as it depends on a series of characteristics specific to the municipality (organizational capacity, personnel, efficiency, and so on) and possibly other factors unknown to the researcher that cannot be under control. The probability of response therefore influences the sample of data that will be obtained - i.e. the probability of response distorts the analysis of the respondents. As is common in these cases, sample selection bias is addressed using the approach proposed by Heckman (1979).

We complete the analysis by exploring the demographic and socio-economic heterogeneity of municipalities in the treatment effects of NRRP funds and considering the difficulties that municipalities have encountered in submitting projects related to the NRRP.

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