

**IES 2022 Innovation & Society 5.0:
Statistical and Economic Methodologies for
Quality Assessment**

BOOK OF SHORT PAPERS

Editors: Rosaria Lombardo, Ida Camminatiello and Violetta Simonacci

Book of Short papers
10th International Conference **IES 2022**
Innovation and Society 5.0: Statistical and Economic
Methodologies for Quality Assessment

Department of Economics, University of Campania “L. Vanvitelli”,
January 27th - 28th 2022



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Ufficio Di Rappresentanza: Via Giacomo Peroni, 400 - 00131 Roma (RM)

CF / P.I. 03167830920 — www.pke.it; e-mail info@pke.it — Privacy

February 2022 PKE s.r.l.

ISBN 978-88-94593-35-8 on print

ISBN 978-88-94593-36-5 online

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Preface

This Book of Short Papers includes all peer-reviewed long-abstracts submitted to the IES2022 conference, titled “Innovation & Society 5.0: Statistical and Economic Methodologies for Quality Assessment”, held at the University of Campania “L. Vanvitelli” on January 27-28, 2022. IES2022 is the 10th meeting of the biennial international conference proposed by the permanent group Statistics for the Evaluation and Quality in Services (SVQS) of the Italian Statistical Society (SIS). The SVQS group, born in 2004, focuses on national research programs and applied research activities, on statistical methods and methodologies for the evaluation of the quality of services in public and private fields. For further information, please visit <https://www.svqs.it/>. IES2022 has been sponsored by the Italian Statistical Society (SIS), the European Network for Business and Industrial Statistics (ENBIS), and the International Association for Statistical Computing (IASC). In addition, also the two SIS groups Statistics and Data Science (SDS) and Enhancement of Public Statistics (VSP) actively supported the conference. IES2022 aims at stimulating a scientific debate on the challenges of Society 5.0 with respect to quality assessment. The conference provides an important moment of reflection for the development of new ideas and methodologies by promoting the rethinking of the open issues in service evaluation within the new paradigm of an interconnected cyber-social system. Service quality assessment represents the starting point for the development of effective policies for private and public institutions, which is crucial for the development of society. Big data, heterogeneous multi-layered structure and designs, cutting-edge analytical tools, and advanced data harvesting techniques have become fundamental for research; nonetheless, they require a continuous effort in terms of proper treatment, interpretation, and supervision to ensure the centrality of human and social problems. In this perspective, IES 2022 main goals are:

- to promote and coordinate the statistical and economic methodologies for the evaluation of a human-centered society emphasizing how statistical thinking, design, and analysis may be of use to a Society 5.0;
- to foster advanced methodological research supporting the assessment of the quality of social services;

- to be a platform where the experts of Statistics, Data Mining, Data Science, Machine Learning, and related disciplines meet for analyzing Big Data.

The high turn-out of the conference, with a total of 107 presentations organized in 22 solicited sessions and 11 contributed sessions, two plenary talks, and the participation of over 300 authors, made evident a very alive interest in evaluation topics. Previous IES editions include:

- IES2009 was held at the University of Brescia (June 24-26, 2009) with selected papers published in special issues of *Electronic Journal of Applied Statistical Analysis (EJASA)* and *Statistica & Applicazioni*;
- IES2011 was held at the University of Florence (May 30 – June 1, 2011) with selected papers published in a special issue of the *Journal of Applied Quantitative Methods*;
- IES2013 held at the University of Milan “Bicocca” (December 9 – 13, 2013) with selected papers published in the *Procedia Economics & Finance* (Elsevier Publisher);
- IES2015 was held at the University of Bari “Aldo Moro” (June 8 – 9, 2015) with selected papers published in a special issue of *Quality & Quantity*;
- IES2017 held at the University of Naples “Federico II” (September 6 – 7, 2017) with selected papers published in special issues of *Social Indicator Research*, *Quality & Quantity*, and *EJASA*;
- IES2019 was held at the European University of Rome (July 4 – 5, 2019) with selected papers published in special issues of *Socio-Economic Planning Science* and *EJASA*.

All IES2022 contributions are based on the development of innovative statistical methodologies or interesting applications. The topics covered in the numerous presentations range over the following fields: Sustainability, Health, Wellness, Sport, Tourism, Education, Training and Research, Bank and FinTech, Transportation, Environment, Enterprise, Cultural changes and values, Industry and Finance, E-commerce, Digital Marketing, Labour Market, Public Administration, Advertising, Political preferences, Justice System. Several short papers deal with the shock of the COVID-19 pandemic and its impact in different areas such as poverty and sustainability, education and distance learning, student satisfaction, environment, health services, and social interactions. From a methodological standpoint, many of the short papers deal with challenging structures such as high-dimensional data, complex survey designs, constrained variability, sparsity, multicollinearity, and multidimensional longitudinal series. A wide range of statistical tools and models have been employed, including functional data analysis, various types of regression models (high-dimensional, logit, quantile, OLR, LASSO, etc.), machine learning algorithms for classification, methods for multi-way data and contingency tables,

generalized discriminant analysis, multidimensional Item Response Theory, PLS-SEM, advanced visualization techniques, compositional data analysis, Bayesian methods and so on. Extended versions of selected IES2022 papers will be included in a special issue of the Computational Statistics Journal titled “High-dimensional Data Analysis and Visualisation to Assess Service Quality” and of Annals of Operations Research Journal, titled “Statistical Methods and Data-Driven for Decision Making in Public Sector”.

Rosaria Lombardo, Ida Camminatiello and Violetta Simonacci
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A permutation test on the relationship between Circular Economy and firm size

Test di permutazione sulla relazione tra Economia

Circolare e dimensione dell'azienda

Stefano Bonnini and Michela Borghesi

Abstract Circular Economy (CE) has recently become the focus of the debate regarding environmental sustainability. An interesting hypothesis concerns the effect of companies' size on the propensity of SMEs to undertake CE activities. The main difficulty of testing this hypothesis is due to confounding factors such as company age and business sector. We propose a multistrata combined permutation test and we apply it to original data concerning Italian SMEs in the metal sector.

Abstract *L'Economia Circolare (CE) è diventata di recente centrale nel dibattito sulla sostenibilità ambientale. Un'ipotesi interessante riguarda l'effetto delle dimensioni delle imprese sulla propensione delle PMI a intraprendere attività di CE. La principale difficoltà di verificare tale ipotesi riguarda fattori di confondimento come l'età dell'azienda e il settore di attività. Proponiamo un test di permutazione multistrato combinato e lo applichiamo ad un dataset originale sulle PMI italiane nel settore metallurgico.*

Key words: permutation test, nonparametric statistics, confounding effect, stratification, circular economy.

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1. Introduction

Circular Economy (CE) provides an important contribution to environmental sustainability mainly (but not only) through the reduction of waste and pollution, the decrease of exploitation of natural resources and the protection of the environment.

Many authors indicate that SMEs are lagging behind (Williamson et al., 2006; Yadav et al., 2018), but they can find challenging to accumulate scientific knowledge and the capabilities required for implementing CE activities and adopting new technologies internally (Ormazabal et al., 2018). Relative to larger firms, SMEs have less access to external finance (Hall et al., 2016), possess lower tangible assets and human capital (Ipinnaiye et al., 2017), and have a smaller market presence (Schot and Steinmueller, 2018). These difficulties often result in SMEs failing to implement or avoiding CE activities altogether (Garcés-Ayerbe et al., 2019; Garrido-Prada et al., 2021).

It seems that firm size (based on number of employees and total turnover) and firms' turnover invested in R&D are significant in explaining within-country variations. Firm size is particularly relevant as medium-sized organizations, both in terms of the number of employees and turnover, are more engaged in CE practices (Hoogendoorn et al., 2015). The decision to undertake CE activities is significantly associated with the number of employees: larger firms are more prone to CE policies (Bassi and Dias, 2019; Bassi and Dias, 2020; Ghisetti and Montresor, 2020).

The main goal of this work is to investigate the relationship between the propensity to undertake CE activities and company size, overcoming the possible confounding effect of firm age. We focus on the metal sector, which is one of the most important in the framework of CE. The metal processing industry has always played a central role in the recovery and recycling of post-consumer metals. Thanks to the recyclability of metals, combined with the versatility that favours their reuse and technologies that increase their durability and lightness, the metallurgical sector has always operated according to an approach of recovery, recycling and reuse, representing a virtuous example of circular economy.

The need of avoiding the possible confounding effects of firm age implies the opportunity of sample stratification and implementation of a multi-strata test. The methodological proposal is based on the application of a nonparametric solution based on a combined permutation test.

Section 2 focuses on the presentation of the statistical problem, followed by the description of the methodological proposal (section 3). The results of the application of the proposed method to a case study, concerning Italian SMEs in the metallurgical sector, are reported in section 4. Section 5 includes concluding remarks.

2. Statistical problem

The main goal of our study is to investigate the effect of firm size on the SMEs' propensity to be involved in CE activities. We deal with a two sample test on

A permutation test on the relationship between Circular Economy and firm size proportions whose H_0 is that the propensity to be circular of medium and small firms is the same. H_1 is that the propensity to be circular of medium firms is greater than that of small firms. We focus on Italian SMEs in the metal sector. The empirical studies that aim to test the effect of a variable on the propensity of enterprises towards CE ignore the possible confounding effects of the economic sector and other factors. Hence, we propose to focus on a specific sector (the metallurgical) and, in order to avoid the possible confounding effect of age, to create strata of firms homogeneous with respect to age, carry out within-stratum tests (comparing medium and small enterprises) and combine the partial tests. Hence, the problem consists in a multistrata test on the proportion for two independent samples.

Let X_j denote the response variable related to the j -th population. X_j takes value 1 if the company undertakes CE activities and 0 otherwise. In our problem $j = 1$ denotes the population of small companies and $j = 2$ the population of medium companies. Under H_0 there is equality in distribution, i.e. all the firms belong to a unique population. Under H_1 there is a stochastic dominance of X_2 (X_2 dominates X_1). In other words, H_1 is equivalent to: $P(X_1 = 1) < P(X_2 = 1)$ or equivalently $\theta_1 < \theta_2$ with $\theta_j = P(X_j = 1)$. Equivalently, within the s -th stratum

$$\begin{cases} H_{0s}: X_{s1} \stackrel{d}{=} X_{s2} \\ H_{1s}: X_{s1} \stackrel{d}{<} X_{s2} \end{cases}$$

where X_{sj} denotes the response variable for the s -th stratum (age group) and the j -th population (size group).

The general problem can be defined according to the union/intersection approach. Hence, the multi-stratum test is

$$\begin{cases} H_0: \bigcap_s H_{0s} \\ H_1: \bigcup_s H_{1s} \end{cases}$$

because the null hypothesis is true if all the partial null hypotheses are true and the alternative hypothesis is true if at least one partial alternative hypothesis is true.

3. Methodological solution

The proposed solution is based on the application of a combined permutation test (Pesarin and Salmaso, 2010). This family of nonparametric methods is suitable when the problem can be broken down into k sub-problems or partial tests. Hence, we have k partial null hypotheses H_{01}, \dots, H_{0k} and k partial alternative hypotheses H_{11}, \dots, H_{1k} and the overall problem can be defined as

$$\begin{cases} H_0: \bigcap_{i=1}^k H_{0i} \\ H_1: \bigcup_{i=1}^k H_{1i} \end{cases}$$

Basically, it is a multiple test where each sub-problem consists in testing the null hypothesis H_{0i} versus the alternative hypothesis H_{1i} . Permutation methods can be used, provided that mean and variance of the populations are assumed to be finite and exchangeability under the null hypothesis holds (Pesarin, 2001). Permutation methods are preferable to parametric solutions when the underlying distribution is unknown or cannot be assumed according to asymptotic theories (hence especially for small samples). Moreover, in the presence of multiple tests such as the one considered, the dependence between the test statistics of the partial problems does not need be explicitly modeled, as in the likelihood approach or other parametric methods. In particular, with the combined permutation tests, the dependence structure is implicitly taken into account by permuting the rows of the dataset and the application of the combining function ψ . The sufficient statistic of permutation tests is represented by the observed dataset.

Without loss of generality, we can assume that the null (partial and overall) hypotheses are rejected for large values of the test statistics. Let $L_i(t) = P(T_i \geq t | \mathbf{X})$ denote the significance level function of the i -th partial test, T_i the test statistic of the i -th partial test and t_i a given value taken by T_i . The (univariate) combined test statistic is $T_\psi = \psi(l_1, \dots, l_k)$ where $l_i = L_i(t_i)$. ψ must be non-increasing function of the arguments and satisfy mild conditions such as: it tends to its supremum (possibly not finite) when one argument tends to zero and, $\forall \alpha \in (0,1)$, the critical value of T_ψ is assumed to be finite and strictly less than the supremum.

For the problem under study, the within-stratum tests represent the sub-problems and a suitable partial test statistic is the difference of sample proportions. Let $\hat{\theta}_{sj} = p_{sj} = f_{sj}/n_{sj}$ be the sample proportion of circular companies in the j -th sample of the s -th stratum, with f_{sj} and n_{sj} absolute frequency of circular companies and sample size respectively in the j -th sample of the s -th stratum. Thus, the partial test statistic is $T_s = \hat{\theta}_{s1} - \hat{\theta}_{s2}$. A possible combination that provides powerful tests when the number of true partial alternative hypotheses is low, is given by

$$T_\psi = \max(1 - l_1, \dots, 1 - l_k)$$

Such combined test is exact, unbiased, consistent and distribution free.

4. Case study

The research question of the case study is: “Is the propensity towards CE of small firms less than that of medium firms, taking into account the possible confounding effect of firm age?”. In order to answer this question, we applied the combined permutation test with stratification described above. The application taken into account concerns the Italian SMEs in the metal sector. The dataset is original and

A permutation test on the relationship between Circular Economy and firm size related to a sample survey about CE on Italian SMEs carried out by telephone interview in January 2020. The sample consisted in 475 Italian firms operating in the metal sector. The variable of interests in the problem are three:

- **response variable** (dummy): it indicates the firm propensity towards CE (1: yes, 0: no). It corresponds to the question “Did you make investments in R&D aimed at reducing the environmental impact of production?”
- **factor** (dummy): it denotes firm size (0: less than 16 employees, 1: 16 or more employees) and represents the “treatment”. The goal is to test the significance of the factor’s effect on the response.
- **confounder** (categorical): it denotes firm age (1: less than 17 years old, 2: from 17 to 36 years old, 3: from 37 to 56 years old, 4: more than 56 years old).

In Table 1 the sample proportions of circular firms within the groups of small and medium SMEs for each age group are reported. It is evident that, for the first two age groups, the propensity to be circular is greater in small companies while for older companies there are similar proportions.

Table 1: Sample proportions of firms that made investments in R&D aimed at reducing the environmental impact of production.

Firm Age	Firm size	
	< 16 employees	≥ 16 employees
< 17 years	0.019	0.004
17 – 36 years	0.021	0.008
37 – 56 years	0.015	0.013
> 56 years	0.006	0.006

By carrying out the combined permutation test, we obtained an overall p-value of 0.645, which indicates no significance at $\alpha = 0.05$. Hence, there is not empirical evidence to reject the hypothesis of null effect of firm size in favor of the alternative hypothesis that medium enterprises have a greater propensity towards CE.

5. Concluding remarks

In the empirical literature on Circular Economy, there is a lack of contributions on the effects of firm size on the propensity towards CE. The few existing works adopt approaches that do not take into account some typical confounding effects, such as those of the economic sector and of the company’s age. We propose the application of a multistrata procedure based on a combined permutation test.

This methodology permits to test complex hypotheses, it is powerful, flexible because distribution-free, and satisfy important properties such as unbiasedness and

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consistency. This approach overcomes the limitations of the parametric methods usually applied to such problems, based on restrictive and unrealistic assumptions.

The application of the test to original sample data concerning Italian SMEs in the metal sector does not bring to empirical evidence in favor of the hypothesis that firm size affects the propensity to Circular Economy.

Acknowledgements

The work was supported by the Italian Ministry of Education, University & Research that funded the departmental development program (DEM – University of Ferrara) for the period 2018–2022, to promote excellence in education and research (“Dipartimenti di Eccellenza”).

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