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Research Paper

Insights on the social and economic factors of the circular economy: A study of the Italian industrial and urban waste recycling sector

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ABSTRACT

In order to achieve the ambitious goals of the European Union (EU) Green Deal, Member States must implement an efficient and modern recycling industry that can combine high environmental standards with high economic performance. According to Eurostat, the amount of waste recovered, both industrial and urban, increased by 33.9% from 2004 to 2020, and the share of recovery in total waste treatment rose, respectively, from 45.9% to 59.1%. Among the EU countries, Italy exhibits the highest waste recycling rate (83.2% in 2020). This paper empirically investigates the economic, institutional, and social aspects that may be correlated to the performance of firms involved in industrial and urban waste recycling. Better performing firms would definitely provide larger benefits to the recycling industry, since turning waste into resources is crucial for the transition to a cleaner, climate neutral and circular economy. Working on a panel dataset of 3715 Italian companies, it emerges that firms performance is positively influenced by several firm-specific factors, such as age of experience, size, degree of specialization and digitalization, and by territorial factors, such as separate collection rate, regional GDP, and regional political ideology.

1. Introduction

Waste recycling is strategic for the implementation of the European Green Deal initiatives and for the establishment of production and consumption systems based on circular economy principles.[1] The European Union (EU) Directive 2018/851, which amended the so-called"Waste Framework" Directive 2008/98/EC, provides the legislative framework for the collection, transport, recovery and disposal of waste. The Directive sets out the targets for preparing for re-use and recycling of municipal waste (from a minimum of 55% by 2025 up to a minimum of 65% by 2035) and imposes restrictions on the amount of waste that country members will have to recycle. Achieving these targets is therefore crucial in creating well-functioning markets for recycled materials in the EU.

According to Eurostat, the total waste generated in 2020 in the EU by all economic activities and households was 2,135 million tonnes or 4.8 tonnes per capita. Table 1 presents data on waste generation by sources (Panel A) and by category (Panel B) in the EU aggregate for the year 2020. Waste from households, which is the main component of municipal waste and so can be considered as urban waste, account for 9.4% of total waste, while the remaining 90% stems from the industrial sector (manufacturing and construction; 48%), from the primary sector (mining, agriculture, etc.; 25%) and from other economic activities. It follows that total waste broadly originates from industrial and urban sources. The predominant categories of waste include mineral waste other than construction and demolition (26%), soils (21%), mineral waste from construction and demolition (14%), recyclables waste (10%), mixed ordinary waste (12.1%), and the remaining share from other waste categories.

Fig. 1 plots total waste treatment in the EU during the 2004–2020 period. The amount of waste recovered increased by 33.9%, from 870 million tonnes in 2004 to 1,165 million tonnes in 2020, while the quantity of waste subject to disposal decreased by 21.5%, from 1,027 million tonnes in 2004 to 806 million tonnes in 2020. The share of recovery in total waste treatment rose from 45.9% in 2004 to 59.1% in 2020.

Table 2 reports the details of the contribution to waste treatment by recovery and disposal in 2020. According to Eurostat, total waste

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[1] Panarello and Gatto (2023).

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generation in the EU-27 in 2020 was 2,153,950 thousand tonnes and total waste treatment amounted to 1,970,710 thousand tonnes.

The share of recovery was mostly related to recycling (39.9%), backfilling (12.7%) and energy recovery (6.5%). The remaining 40.9% of total treated waste was landfilled, incinerated without energy recovery, or disposed of otherwise.

To achieve the ambitious goals of the European Union, Member States must implement an efficient and modern recycling industry that can combine high environmental standards with high economic performance. While the environmental benefits of waste recycling have been extensively studied by the existing literature, it would be worthy of investigating the economic and social aspects that may be correlated to the performance of firms involved in the waste recycling sector. Better performing firms would provide larger benefits to the recycling industry.

Focusing on recycling, which is the topic addressed by this paper, it emerges that Italy is the most virtuous country in the EU in terms of waste recycling, showing a recycling rate of 83.2% in 2020. According to the report of the European Commission (2023), Italy is on track to meet the 2025 targets for the preparing for re-use and the recycling of municipal waste and for the recycling of all packaging waste, though there are significant differences among regions and therefore additional progresses are expected in landfilling municipal waste. Table 3 presents data on municipal waste treatment in the EU-27 and Italy for the same year. Total municipal recovery rates were 76% for the EU and 77.3% for Italy, with recycling activities accounting for 49.58% in the EU and 56.54% in Italy.

Given the strategic role played by waste recycling in modern economies, and given the good outcomes achieved by Italy in waste recycling, the goal of this paper is to investigate which economic and social factors could influence the performance of Italian firms working in the recycling industry. We perform a random-effects panel regression for a sample of 3715 Italian firms extracted from AIDA database, involved in waste recycling both as a primary and as a secondary activity according to the Ateco codes and the Rae codes provided, respectively, by the Italian National Statistical Institute (Istat) and the Bank of Italy. The time horizon spans from 2013 to 2021. Reviewing the existing literature, we develop and discuss four research hypotheses, which allow us to suppose performance to be dependent upon a battery of macroeconomic and social factors. As well as traditional performance indicators such as Return on Equity (ROE), Return on Assets (ROA), and Earning before interest taxes depreciation and amortization (EBITDA), we employ total revenues, added value, Return on Investments (ROI), and markup, to gauge performance. Among the regressors, we include two key variables, i.e., the degree of specialization of firms involved in recycling activities and the degree of digitalization of firms, and other control variables computed at local level where each firm operates, such as the regional real GDP per-capita, the provincial separate waste collection rate, and the political ideology governing the region in which each firm operates.

Our research contributes to the existing knowledge about the influence of economic and social factors on the performance of Italian firms working in the recycling industry in several ways. To the authors' knowledge, until now the assessment organization's performance in the Italian recycling contexts has been explored by using only a limited sample of firms (Franceschelli et al., 2019, Ghisellini and Ulgiati, 2020) or at local level (Gastaldi et al., 2020). In this perspective, the data used in our paper represent a unique source of data which provides detailed information at firm-level by including also historical data. Therefore, it offers comprehensive data coverage and reliable data to support informed decision-making processes.

Therefore, this paper addresses the following research questions: i) does the performance of firms involved in recycling depend upon internal factor, such as experience and size? and ii) what about external factors at territorial level, such as regional GDP per-capita, separate collection rate, and political ideology of government? iii) does the degree of specialization and digitalization matter?

The paper is organized as follows. Section 2 provides a review of the related literature. Research hypotheses are developed and discussed in Section 3. Section 4 provides data description and descriptive statistics, while Section 5 is devoted to methodology and econometric specification. Results are discussed in Section 6, and Section 7 concludes.

2. Related literature

The economic literature on the waste recycling industry consists of three main strands. The first one investigates the benefits provided to the environment from an efficient recycling system, the second strand analyzes the effects of the recycling activity on economic growth and social welfare, while the third one investigates the factors that may influence the efficiency, the economic performance and employment of the companies involved in the recycling sector.

Improving the condition of the natural environment is surely one of the first significant effect of an efficient waste recycling system. Recycling helps saving natural resources and enery (Dewulf et al. 2010, Ross and Evans, 2003; Acuff and Kaffine, 2013; Cooper et al., 2016; Ayodele et al., 2018), and allows to reduce greenhouse gas (GHG) emissions (King and Gutberlet, 2013; Liu et al., 2018a).

A growing body of research is studying the contribution of the recycling activity to socio-economic development (see, among all, Ayodele et al., 2018; Lino and Ismail, 2013; Batool et al., 2008; Agarwal et al., 2005, local employment (Liu et al., 2020; Filho et al., 2019; Beccarello and Di Foggia 2016; McMahon et al., 2021; Valenzuela-Levi et al. 2021).In addition, recycling activities carried out in a context of a circular economy can generate positive effects on social welfare because they allow to overcome the distortions created by alternative policies on waste control (e.g., waste taxation), thus generating benefits for both consumers and businesses (Liu et al. 2018b, Correani et al., 2023). The relevance of per-capita income in affecting environmental degradation has been well investigated by the literature on the Environmental Kuznets Curve (EKC) and only recently applied to recycling and waste production (Dinda, 2004; Mazzanti-Zoboli, 2009). For instance, Stern (2004) shows that waste production increases at the initial stage of

Table 1
Generation of waste by economic activities and households (Panel A), and by category (Panel B) in the EU-27 (2020, % of total waste generation).

Panel A								
Agriculture, forestry and fishing	Mining and quarrying	Manufacturing	Energy	Waste water	Construction	Services	Wholesale of waste and scrap	Households
0.99	23.39	10.65	2.33	10.80	37.47	4.44	0.49	9.44
Panel B								
Chemical and medical wastes	Recyclable wastes (metal, plastic, paper, glass, wood)	Animal and vegetal wastes	Mixed ordinary waste (including households)	Mineral waste from construction and demolition		Other mineral wastes	Soils	Others
2.32	10.01	4.31	12.1	14.19		26.06	20.80	10.20

Source: Eurostat (online data code "env_wasgen").

economic development (because of increasing consumption leading to higher levels of waste) to reduce in a second stage when income exceed a threshold, and communities start to develop more pro-environmental behaviors. However, more recently researchers suggested an inverted N-type trajectory (İçen and Çil, 2023), where the relationship between income and waste generation starts growing again after a first reduction, to become inverted in a third step when both higher income and sustainable consumption habits consolidate.

A recent strand of the literature is focusing on the performance of the recycling industry, but little attention has been paid to the analysis of the determinants that may affect the economic performance of recycling firms. Investigating such determinants is crucial in the light of the existence of a positive relationship between environmental performance of firms, so far focused on sectors other than recycling, and their economic value (Dal Maso et al, 2023; Cheng et al., 2012; Ohnishi et al., 2012; Taghipour et al., 2022; Nilashi et al., 2023).

Our paper mostly contributes to this last strand of the literature, and it is mainly related to Franceschelli et al. (2019) who, to the best of our knowledge, were the first ones to investigate the potential factors that could influence the performance of recycling firms, measured by traditional indicators such as ROE, ROA, and EBITDA. The authors find that the performance of recycling firms is positively correlated with their experience, size and degree of innovation. Our research presents a distinct focus compared to the study conducted by Franceschelli et al. (2019) in several key aspects:

- main goal, while Franceschelli et al. (2019) concentrate on the social responsibility implications of recycling activities, our investigation aims to delve into the industrial organizational dimensions of the recycling sector, specifically highlighting the influences of specialization, digitalization, and political ideology;
- methodology, there is a notable difference in the methodologies employed, both in terms of variables and econometric techniques employed. We run a random effects panel regression on a dataset of over 3,500 Italian recyclers, focusing on variables such as specialization, digitalization, markup, and political ideology. In contrast, Franceschelli et al. (2019) adopt an OLS regression on a sample of 87 Italian recyclers, examining variables like the representation of women on boards and environmental certifications.

Table 2
Waste treatment in the EU, by type of recovery and disposal (2020, % share of total waste treatment).

	Recovery Recycling	Backfilling	Energy recovery	Total % of recovery	Disposal Total % of disposal
EU	39.91	12.66	6.54	59.11	40.89
Italy	**83.22**	**0.21**	**5.50**	**88.93**	**11.07**
Belgium	74.10	11.23	7.24	92.57	7.43
Slovakia	63.99	0.57	6.06	70.62	29.38
Latvia	63.96	3.03	8.40	75.39	24.61
Croatia	55.68	4.78	5.06	65.52	34.48
Denmark	55.59	16.65	20.33	92.56	7.44
Spain	54.71	5.14	3.99	63.84	36.16
France	54.24	10.17	7.69	72.10	27.90
Czech Republic	51.13	33.77	3.91	88.80	11.20
Netherlands	49.37	0.00	7.72	57.09	42.91
Portugal	45.20	8.65	10.89	64.73	35.27
Slovenia	44.52	47.22	2.68	94.43	5.57
Estonia	44.22	14.35	2.17	60.74	39.26
Germany	43.96	26.06	11.81	81.82	18.18
Luxembourg	41.54	32.49	3.08	77.10	22.90
Lithuania	39.48	2.88	10.69	53.05	46.95
Cyprus	37.71	0.81	14.05	52.58	47.42
Malta	37.56	53.31	0.00	90.87	9.13
Poland	36.34	35.31	2.68	74.33	25.67
Austria	33.97	16.11	4.00	54.08	45.93
Hungary	33.70	39.17	6.36	79.23	20.77
Ireland	32.58	2.61	36.21	71.40	28.60
Greece	23.75	9.13	1.83	34.71	65.29
Sweden	11.91	2.72	6.18	20.81	79.19
Finland	9.54	0.88	5.52	15.94	84.06
Bulgaria	7.74	0.00	0.60	8.34	91.66
Romania	5.17	0.90	1.42	7.49	92.51

Source: Eurostat (online data code: "env_wastrt").

3. Research hypotheses

Following the existing literature, we develop and discuss our research hypotheses connected to investigation of the potential determinants that may affect the economic performance of Italian recycling firms. Firms that have been in the market for a longer time than others usually exhibit higher productivity because of learning by doing (Cohen and Levinthal 1989). This aspect may be very noticeable for

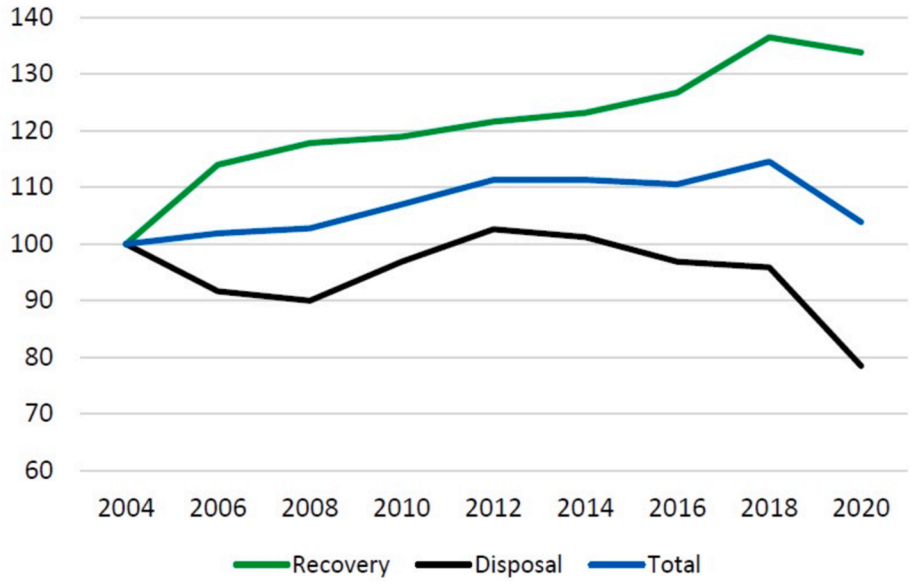

Fig. 1. Waste treatment in the EU (2004–2018, 2004 = 100).
Source: Eurostat (online data code: "env_wastrt")

Table 3
Municipal waste treatment in the EU-27 aggregate and Italy in 2020 (% of total municipal waste treatment).

	Recovery			Disposal
	Recycling (a)	Energy recovery (b)	Total recovery (a) + (b)	
EU-27	49.58	26.52	76.1	23.9
Italy	56.54	20.75	77.29	22.71

Source: our elaboration on Eurostat data (online data code "env_wasmun").

companies active in recycling, as they have to use ever-changing technologies due to increasingly binding national and international standards. Therefore, experience assumes a strategic role for firms in order to remain competitive and to overcome modern environmental constraint. Following Franceschelli et al. (2019) and Thornill and Amit (2003) we consider firm age as a proxy of firm experience. In addition firm size, measured by the number of employees, emerges to be positively correlated with firm performance (Franceschelli et al., 2019; Schoonjans et al., 2013; Hoque and James, 2000). The European Green Deal imposes an increasingly high percentage of material recovery from waste and this task can be efficiently carried out especially by large companies able to i) take advantage of economies of scale, given the increasing amount of materials to be recycled, and ii) make expensive investments in cutting-edge and sophisticated technologies required for waste recovery procedures. Therefore, we expect better performance for larger firms. This discussion leads us to formulate our first hypothesis.

Hypothesis 1. *The economic performance of recyclers is positively affected by both their age* (*years of experience*) *and size* (*number of employees*).

It is reasonable to suppose that the degree of activity diversification can be a relevant factor for performance. The recycling industry, especially in Italy, is characterized by the presence of very heterogeneous firms. Highly specialized firms carry out recycling both as a primary and secondary activity, while others, less-specialized, carry out recycling only as a primary or secondary task and they are also engaged in other complementary or totally different activities (e.g., garbage and sanitation services, transport and production and sale of textile fibers). On the one hand, differentiating the business activity may increase performance, thanks to the accumulation of intra-industry diversification experience (Zahavi and Lavie, 2013), or to more profitable reallocation of resources of firms operating in mature markets (Levinthal and Wu, 2010); on the other hand, diversification could reduce business performance due to various frictions, such as, agency problems stemming from a poor governance structure (Palia, 1999), the need for different skills to operate in different markets (Krug and Falaster, 2022; Capon et al., 1988), and capital misallocations (Rajan, Servaes and Zingales, 2000). Given that the waste recycling industry is continuously evolving and characterized by expensive and specific technological investments, we expect better performance for more specialized firms. This leads us to formulate the second research hypothesis.

Hypothesis 2. *Firms that are specialized in recycling activities have better performance than firms that diversify their activities.*

According to Nicolli et al. (2012), waste recovery is particularly affected by market failures that can be effectively overcome by technological innovation. Asymmetric information regarding the quality of waste, as well as consumption and technological externalities, may generate inefficiencies and reduce both recycling rates and firm performance.[2] To address such shortcomings of the recycling market, the authors suggest several solutions based on digitizing trade to reduce transaction costs, introducing technological innovations that can accurately select materials and thus overcome technological externalities, and promoting innovative and digital procedures for evaluating the chemical and physical properties of recycled inputs to reduce consumption externalities. Thus, we expect a positive and significant relationship between innovation, digitalization and performance according to the following hypothesis.

Hypothesis 3. *The economic performance of recyclers is positively correlated with technological innovation and business digitalization.*

External macroeconomic conditions in which recycling companies operate, as well as the political environment, and the degree of efficiency of the waste collection system, can generate effects on firms performance. For instance, an increase in GDP per capita is associated to stronger preferences for environmental sustainability and larger demand for recycled goods (Liu et al., 2020). Therefore, it is reasonable to observe more developed and high-performing recycling industries in wealthier communities (Kumar et al.,2017; Boubellouta and Kushbrandt, 2023). The European Union assigns each Member State the responsibility for organizing its waste management systems and associated recycling activities. Italy has complied with this directive through Legislative Decree No. 152/2006, which delineates the responsibilities of Municipalities, Provinces, and Regions concerning the planning and regulation of waste management operations.[3] Regions play a central role in coordinating local authorities and ensuring the proper flow of funds to municipalities. Therefore, we believe that local economic conditions, reflected by regional GDP, are key drivers of both production and consumption patterns, which in turn influence waste generation and recycling activities. Regional GDP reflects the economic output of a given area, offering valuable insights into industrial activity, urbanisation, and public investments, all of which are interconnected with waste production and management. Thus, we expect more efficient and performing recycling systems for those Regions showing higher average income due to greater resources that can be allocated towards waste recycling efforts.

Local political ideology and government preferences can affect the performance of green industry (Yi and Feiock, 2014; Liu et al., 2020).It is reasonable to suppose that stringent environmental constraints may have a negative effect on performance because of the higher costs faced by firms to comply with new environmental standards, and we expect to observe a positive influence of conservatives ideology on economic performance. The motivation behind this expected result is outlined in recent studies (Schulze, 2021; Lundquist, 2024), which indicate that political parties with left-leaning ideologies in government often favor non-market-based approaches to environmental policy. These approaches typically involve centralized planning, stricter regulations, and increased public control and oversight. Conversely, right-leaning parties tend to prefer market-based instruments, such as incentivizing private sector solutions to achieve a better balance between environmental sustainability and economic performance. The ideological debate surrounding the implementation of an efficient waste recycling system often implies disagreements on questions about costs, government intervention, regulation of firms' behavior and effectiveness. Right-wing parties pay more attention to economic performance to benefit upper-income classes and have often more anti-recycling ideas (Lybecker et al., 2013), whereas left-leaning parties tend to focus their efforts on

[2] Consumption externalities occur when buyers lack information about the suitability of a certain recycled material for a specific use. Technological externalities occur when a manufacturer makes its product in such a way that subsequent recycling of materials is very expensive.

[3] https://www.cial.it/*quadro*-normativo-rifiuti/.

improving social welfare by, for instance, increasing energy efficiency, public education (Wang et al., 2022; Arslan et al., 2024) and promoting a pro-recycling approach even at the cost of economic efficiency.

More efficient waste collection system, such as separate collection, fosters the effectiveness of waste recovery thus providing a great stimulus to the growth of the recycling industry. Local separate collection represents the local supply of waste, which serves as a stimulus for the demand from recyclers. It is plausible that the presence of strong and well-performing local recycling firms could improve local recycling facilities, thereby resulting in an increased rate of separate collection, suggesting a potential reverse causality. However, recent literature confirms that recycling behavior is primarily influenced by factors such as education, the perceived condition of the local environment, household interest in environmental issues, political factors, and social pressure (see, among others, Khan et al., 2020; Corrado et al., 2022; Bruno et al., 2022). We align with this body of literature and posit that it is the rate of separate collection—shaped by established recycling habits—that influences the development and performance of the recycling industry, rather than the reverse. Following this discussion, we formulate the final hypothesis.

Hypothesis 4. *The economic performance of recycling firms is positively correlated with conservative governments, higher regional real GDP per-capita, and higher separate collection rate.*

4. Data and descriptive statistics

To analyze the economic and social factors influencing the performance of firms in the recycling sector, we have collected data from the Bureau van Dijk AIDA database (AIDA)[4] for Italian firms involved in the recycling industry, both as a primary and/or a secondary activity, from 2013 to 2021 (yearly observations). Overall, we work on a panel consisting of 3715 companies.

We employ EBITDA, ROA, ROE, ROI, total revenues, added value, and markup, as indicators of firms performance. Markup allows us to test the performance of a firm in terms of market power. We compute markup as the ratio between the added value and production costs, as proposed by Griffith et al. (2010). This is a measure of firm's profitability and can been considered as a proxy for the Lerner index under the assumption of constant returns to scale.[5] Firms age has been computed as the number of years since each firm has been established.

We have also gathered data on the separate waste collection rate at provincial level, and on the political ideology governing the region in which each firm operates. The separate collection rate can be considered a good indicator of environmental awareness among people, while political ideology allows us to investigate the different approaches that regional governments may have in implementing environmental protection. Data on political ideology have been retrieved from the digital archive of the Italian Ministry of Interior,[6] while provincial separate collection rates and regional real GDP per capita have been obtained from Istat.

The degree of digitalization of business has been proxied using a variable from the AIDA database which tells us whether each firm has implemented or not a website devoted to managing the relations with suppliers and customers. In order to determine the degree of specialization of recycling firms, we have relied upon the Ateco and Rae classification codes of economic activities. The Rae code, Branch of Economic Activity, identifies the sector of intervention of a company. It is a three-digit code that is assigned by the Bank of Italy according to the assignment tables derived from the NACE nomenclature. The Rae, in fact, serves precisely to guarantee the uniformity of real and financial accounting and to ensure consistency with the Istat and NACE statistical classification. We consider firms that conduct recycling as a primary activity those identified by the Ateco-38 code of the Ateco classification, while firms that conduct recycling as a secondary activity those identified by the Rae-620 code.[7] Therefore, we identify specialized firms with those ones that carry out waste recycling both as a primary and secondary activity (i.e., Ateco = 38 and Rae = 620), while non-specialized firms with those ones that conduct waste recycling only as a primary or secondary activity (i.e., either Ateco = 38 or Rae = 620). It emerges that 1374 firms are specialized in recycling activity (37% of the entire sample) while the remaining 2025 (54.5%) are not (see Table 4).

Although this classification refers to "specialized firms" as those whose primary and secondary activities are exclusively recycling-related, it does not account for specialization based on specific materials (e.g., packaging). This represents an additional level of specialization that falls outside the scope of our study.

Table 5 reports the main descriptive statistics for the quantitative variables used in our paper by including the number of observations, mean, standard deviation (St. Dev.), minimum and maximum values, while pairwise correlation coefficients are reported in Table 6. We point out that *Revenues*, *Added value*, *EBITDA*, *Size*, *Separate collection rates*, and *Regional income* are expressed in natural logarithm.

5. Econometric specification

We employ a random effect panel regression model to investigate the potential factors that may influence the performance of recycling firms. To test our four Hypotheses, we run the following regression equation:

$$\pi_{i,t;k} = \alpha + \beta_1 Age_{i,t} + \beta_2 Size_{i,t} + \beta_3 Spec_{i,t} + \beta_4 Area_{i,t} + \beta_5 Innov_{i,t} + \beta_6 Digit_{i,t} + \beta_7 SepColl_{i,t-1} + \beta_8 PolEnv_{i,t-1} + \beta_9 \mathrm{Reg}Inc_{i,t} + \varepsilon_{i,t} \quad (1)$$

where $\pi_{i,t,}$ is the dependent variable represented by the *k-th* performance indicator of recycler *i* at time *t*, with $k = 1,\ldots,7$. The performance indicators are, respectively, added value, total revenues, EBITDA, ROA, ROE and ROI, and markup. Added value, total revenues and EBITDA are expressed in terms of natural logarithm. The regressors included are the age of firms ($Age_{i,t}$), their size ($Size_{i,t}$) as the natural logarithm of the number of employees, the level of innovation ($Innov_{i,t}$) which is a dummy variable taking value 1 if the company has acquired patents in year *t*, the dummy variable ($Digit_{i,t}$) which is equal to 1 if the firm has digital instrument (website) to manage its deals with suppliers and customers, and the geographical dummy variable ($Area_{i,t}$) which takes value 1 if the firm is operating in northern Italy (Valle d'Aosta, Piemonte, Liguria, Lombardia, Veneto, Friuli Venezia Giulia, Trentino Alto Adige, Emilia Romagna) or zero if it is located in Center or South of Italy.

Table 4
Number of specialized and non-specialized firms (percentages over total number of firms in round brackets).

	Secondary activity		
Primary activity	Rae = 620	Rae ≠ 620	Total
Ateco = 38	1374	2025	3399 (91.5 %)
Ateco ≠ 38	316	–	316 (8.5 %)
Total	1690 (45.5 %)	2025 (54.5%)	3715 (100 %)

[4] Computerized analysis of Italian companies (Analisi Informatizzata delle Aziende Italiane), managed by the Bureau van Dijk.

[5] The ratio is biased upwards (downwards) if the returns to scale are decreasing (increasing). Of course, the price–cost margin (Lerner index) would be a more robust indicator of competition among firms (Boone 2000) but unfortunately it is not available at firm level.

[6] https://elezioni.interno.gov.it/.

[7] The Ateco-38 code includes"Waste collection; Treatment and disposal activities; Recovery of materials". The Rae-620 code includes"Recovery of goods (scrap metal, old metals, old papers, cloth and other products of salvage and demolition)".

Table 5
Summary statistics of the variables considered.

Variable	N.	Mean	St. Dev.	Min	Max
Revenues	27,266	7.123	1.893	0.000	13.573
Added value	26,653	5.994	1.826	−5.809	13.095
EBITDA	24,953	4.950	1.850	−5.521	12.208
ROA	28,870	4.245	13.717	−147.530	200.860
ROE	27,131	9.823	27.588	−149.530	148.940
ROI	18,342	7.342	10.493	−29.960	30.000
Markup	25,984	0.377	0.213	0.000	1.000
Age	29,517	16.185	12.130	0	110
Size	26,346	2.254	1.359	0.000	8.976
SepColl	29,720	3.872	0.464	1.792	4.481
RegInc	33,435	5.524	0.295	4.999	6.008

$Spec_{i,t}$ is a dummy variable denoting the degree of specialization of firm i at time t, which is equal to 1 if recycling is carried out both as primary and secondary activity. $SepColl_{i,t-1}$ is the logarithm of the one-lag separate collection rate of the province where each firm operates. $PolEnv_{i,t-1}$ is a dummy variable denoting the political ideology governing the region at t-1 in which the recycling firm operates: it takes value 1 if the region is governed by conservative (right) parties, and zero otherwise. We employ the one-lag variables for separate collection rate and for political ideology since we suppose their changes to produce non-immediate effects on firms performance. For instance, separate collection takes time to be properly processed and transformed into raw material to be placed back on the market; likewise, a change in government political ideology does not immediately translate into new economic policies in the recycling sector. The variable $RegInc_{i,t}$ is the natural logarithm of real GDP per-capita of the region where firm i operates. $\varepsilon_{i,t}$ is the error term.

In contrast to the fixed effects model, the random effects model enables the inclusion of time-invariant explanatory variables, such as digitalization, political ideology, and geographical area. The observations can be regarded as a random sample from a specified population, as the Aida database does not provide comprehensive data on all companies operating in the recycling sector; thus, the random effects model is deemed more suitable than the fixed effects model. In addition, the Breusch-Pagan Lagrange Multiplier test yields a p-value of less than 0.05, confirming that the random effects model is the appropriate choice compared to pooled ordinary least squares (OLS) regression.

6. Results

Table 7 reports regression results. Overall, it emerges that estimation

Table 6
Pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Revenues	1.00										
(2) Added value	0.85***	1.00									
(3) EBITDA	0.80***	0.86***	1.00								
(4) ROA	0.12***	0.11***	0.20***	1.00							
(5) ROE	0.07***	0.07***	0.15***	0.66***	1.00						
(6) ROI	0.13***	0.13***	0.21***	0.78***	0.63***	1.00					
(7) Markup	−0.14***	0.19***	0.06***	0.22***	0.13***	0.14***	1.00				
(8) Age	0.32***	0.33***	0.33***	0.02***	−0.07***	−0.00	−0.00	1.00			
(9) Size	0.72***	0.83***	0.64***	0.01**	−0.00	0.05***	0.21***	0.26***	1.0000		
(10) SepColl	0.15***	0.10***	0.12***	0.04***	0.01**	0.04***	−0.10***	0.17***	0.02***	1.00	
(11) RegInc	0.18***	0.12***	0.15***	0.01***	−0.02***	−0.00	−0.15***	0.19***	0.02***	0.50***	1.00

*, **, *** denote, respectively, statistical significance at 10%, 5% and 1% level.

Table 7
Estimation results for performance indicators and markup.

	Model (1) Revenues	Model (2) Added value	Model (3) EBITDA	Model (4) ROA	Model (5) ROE	Model (6) ROI	Model (7) Markup
$Age_{i,t}$	0.021***	0.022***	0.033***	0.014	−0.233***	−0.058***	0.0004
	(0.001)	(0.001)	(0.002)	(0.013)	(0.027)	(0.011)	(0.000)
$Size_{i,t}$	0.788***	0.868***	0.605***	0.594***	1.192***	0.676***	0.034***
	(0,015)	(0,012)	(0,016)	(0,134)	(0,258)	(0.114)	(0,002)
$Spec_{i,t}$	0.197***	−0.0606**	0.0713*	1.692***	2.085***	1.065***	−0.054***
	(0.036)	(0.025)	(0.039)	(0.318)	(0.614)	(0.283)	(0.006)
$Area_{i,t}$	0.244***	0.078**	0.138**	0.169	−2.889***	−1.069**	−0.034***
	(0.049)	(0.037)	(0.056)	(0.444)	(0.925)	(0.417)	(0.008)
$Innov_{i,t}$	0.033**	0.033**	0.050***	−0.219	−0.942**	0.068	−0.005**
	(0.016)	(0.013)	(0.018)	(0.234)	(0.480)	(0.229)	(0.002)
$Digit_{i,t}$	0.474***	0.311***	0.460***	0.289	−0.440	0.374	−0.0511***
	(0.039)	(0.028)	(0.044)	(0.352)	(0.677)	(0.313)	(0.006)
$SepColl_{i,t-1}$	0.183***	0.181***	0.268***	1.965***	3.674***	1.216***	0.000
	(0.030)	(0.023)	(0.033)	(0.342)	(0.718)	(0.314)	(0.005)
$PolEnv_{i,t-1}$	0.025	0.027**	0.079***	0.159	1.752***	0.513**	0.001
	(0.017)	(0.016)	(0.022)	(0.263)	(0.563)	(0.248)	(0.003)
$RegInc_{i,t}$	0.427***	0.223***	0.159*	−1.487**	−2.110	−0.330	−0.062***
	(0.075)	(0.057)	(0.087)	(0.726)	(1.470)	(0.672)	(0.013)
Constant	1.492***	1.561***	0.668	2.923	10.34	4.376	0.711***
	(0.406)	(0.315)	(0.476)	(3.901)	(7.790)	(3.562)	(0.0714)
Firms	3664	3621	3560	3684	3630	3342	3602
Obs.	23425	22904	21355	23652	22447	14934	22437
R2	0.584	0.720	0.451	0.006	0.015	0.011	0.11

*, **, and *** denotes, respectively, statistical significance at the 10%, 5%, and 1% levels. Standard errors in parentheses. The p-value of F test to see whether all the coefficients in the model are different from zero is less than 0,05. The Breusch-Pagan Lagrange Multiplier test gives a p-value less than 0,05 confirming that the random effect model is the appropriate choice with respect to a simple OLS regression.

results suit our research Hypotheses. We are going to discuss first the results for performance indicators (Models 1–6), and then the results for markup (Model 7).

An additional year of activity exhibits an increase of revenues and added value by 2%, and of EBITDA by 3%. The findings suggest that a greater level of experience among firms operating in the recycling industry is associated with increased performance indicators. Furthermore, larger firms, in terms of number of workers, are better equipped to manage the growing volume of waste in line with the increasingly stringent European regulations on recycling. Indeed, an increase by 1% of the number of workers generates an increase of 0,8% in revenues and added value, and of 0,6% in EBITDA, and an increase by almost 0.6 to 1.2 percentage points in ROA, ROE, and ROI. This implies that Hypothesis 1 is fully satisfied for revenues, added value and EBITDA, while it is partially satisfied for ROA, ROE and ROI. The effect of experience (Age) on the economic performance of recyclers emerges, indeed, to be ambiguous. On the one hand, older firms are generally more productive due to learning by doing and their knowledge of the market, and this explains the positive effect of Age on Revenues, Added value and EBITDA (Parida et al. 2016). On the other hand, older recyclers may have a higher amount of equity and investment resulting in lower ROE and ROI indicators with respect to younger firms (Burlina 2019, Cisi et al. 2018).

According to Hypothesis 2, the estimated coefficients for the degree of specialization emerges to be positively correlated with revenues and EBITDA (Models 1 and 3), while it is negatively linked with added value. Those firms highly specialized in the recycling sector exhibit, on average, an increase in revenues and in EBITDA by, respectively, 20% and 7%, w.r.t. those firms that also carry out activities other than recycling. Specialized firms also exhibit, on average, higher ROA, ROE, and ROI by, respectively, 1.6, 2, and 1 percentage points, w.r.t. those firms that are not specialized.

The waste recycling industry is characterized by expensive and specific technological investments to comply with evolving European legislation on recycling, thus it is reasonable to observe a better performance for specialized firms. The lower added value of specialized firms compared to non-specialized ones may be attributed to the increasing costs of investing in specific recycling technology. Regarding digitalization, we observe a positive and statistically significant correlation with revenues, added value, and EBITDA thus confirming Hypothesis 3, while no significant relationship emerges between digitalization and ROA, ROE, and ROI. On average, digitalized recyclers show an increase in revenues, EBITDA, and added value by, respectively, 47%, 31%, and 46%, with respect to non-specialized firms. The digitalization process speeds up relationships with customers and suppliers, and promotes innovative procedures for evaluating the chemical and physical properties of recycled inputs, allowing the reduction of asymmetric information and transaction costs. Firms purchasing patents show on average higher revenues (by 2%), EBITDA (by 6%), and added value (by 4%), and lower ROE (−0.9) w.r.t. those recyclers that do not purchase patents. Innovation allows firms to increase productivity, overcome technological and consumer externalities, and reduce transaction costs. However, as Widianingsih et al. (2023) point out, innovation increases potential risks due to uncertainty and this may have a negative effect on performance indicators such as ROE.

The results indicate that the influence of digitalization and innovation varies when assessed through the lenses of ROA, ROE, and ROI (Models 4–6) in comparison to other performance indicators (Models 1–3). Generally, these factors are not statistically significant, as also shown by Franceschelli et al. (2019). Possible explanations for this lack of significance include the recycling sector's failure to achieve full innovation and digitalization capabilities, as evidenced by the fact that 70% and 45% of the firms in our sample have, respectively, neither acquired patents nor implemented digitalization procedures. Additionally, it is noteworthy that many patents provide only limited protection (Griliches et al., 1991). Innovation exerts a significant negative effect on ROE, because the procurement of patents constitutes an investment that enhances the company's intangible assets, potentially leading to an increase in equity since patents are recognized as part of the owner's equity. However, ROE may decline if net income does not rise commensurately. The acquisition of patents incurs associated costs, including legal and administrative expenses, which can adversely impact net income in the short term. If these costs exceed the initial benefits obtained from the patents, a negative effect on ROE could be observed. This situation further clarifies the negative, albeit not statistically significant, effect of patents on ROA.

Regarding regional differences, it emerges that firms located in the north of Italy exhibit, on average, i) higher revenues, added value, and EBITDA, and ii) lower ROE and ROI, w.r.t. those firms located in the Centre or South of Italy. Italy has historically been shaped by a significant territorial divide between its northern and southern regions. In the context of waste management, particularly concerning rates of separate collection, there exists a marked disparity across various Italian regions (Agovino et al., 2019). Citizens in the northern regions exhibit more pro-environmental attitudes compared to their southern counterparts (ISPRA, 2023). This disparity suggests that recyclers in the northern regions experience greater social pressure, resulting in higher investment costs and increased shareholders' equity. If these costs are not accompanied by a proportional rise in net income, they are likely to adversely affect the ROE and ROI metrics.

Other control variables, i.e., provincial separate collection rate, political environment at the regional level, and regional real GDP per capita, are included to capture local economic aspects and to test the robustness of our findings. The separate collection rate as well as the dummy on the political environment lagged by one period enter positively and statistically significant in almost every regression model (except for political environment in Models 1 and 4). This outcome tells us that an increase by 1 % in the separate collection rate in the previous year generates an increase in revenues, added value, and EBITDA by, respectively, 0.18%, 0.18%, and 0.27%, and an increase in ROA, ROE, and ROI, by, respectively, 2, 3.7, and 1.2 percentage points, with all estimated coefficients statistically significant at the 1 % level. The estimated coefficients of political environment and regional GDP broadly show a positive, and statistically significant, correlation with performance indicators, implying that i) more conservative regions exhibit, on average, better performance then those ones governed by less conservative parties, and that ii) regions with higher real GDP per capita foster the performance of recycling firms. These outcomes meet Hypothesis 4, implying that the macroeconomic and political conditions in which the recycling firms work can play a crucial role in influencing the efficiency of recyclers.

We consider markup among the dependent variables to investigate the potential implications on market power of recycling firms. We observe that specialized firms show on average a lower market power with respect to non-specialized firms (−0.05). This outcome is in line with the results obtained for the estimated coefficients on added value (model 2): higher costs associated to higher degree of specialization imply an erosion of market power, and furthermore high specialization could expose recyclers to a higher degree of competition. Digitalization is negative and statistically significant for markup implying that digitalized firms show, on average, a reduction in mark-up by 0.05 points with respect to non-digitalized firms. Digitalization fosters the dissemination of firm-specific information allowing the reduction of asymmetric information and transaction costs.

To gain a deeper understanding of the reasons behind this result, it is beneficial to examine in detail the characteristics of competition within the recycling industry, which develops on two different levels. First, recyclers compete for waste collection services; second, competition among recyclers is at the level of procurement and provision of post-collection services. This second type of competition (which is the focus of our analysis) is of greater interest as it can promote innovation and efficiency in recycling processes (Corral-Marfil et al., 2021).

Studies reveal that the degree of competition is very high due to industry-specific characteristics. The diverse range of materials and treatment methods utilized by waste companies, along with society's constantly evolving production and consumption patterns, creates significant uncertainty for firms in this sector. Thus, companies must continually adjust their operations in response to external changes to remain competitive (Nogueira, 2023). Moreover, the recycling sector is marked by continuous technological advancement; mostly, digitization and artificial intelligence play an increasingly central role in both the management of recycling processes and services (Elia et al., 2015; Berg et al., 2020). Given that high competition is associated with lower markup, we expect a negative relationship between market power of the recycler and its propensity to innovate and digitize its business.

7. Conclusions and policy implications

The higher the efficiency of the recycling sector and the performance of firms involved in industrial and urban waste recycling, the better the provision of social and environmental benefits.

In line with the existing literature, our results confirm the existence of a positive correlation between firms performance and their age and size. We also find that recycling firms buying patents show better performances with respect to those ones that do not.

An interesting novel result is that specialization and digitalization of recycling firms increase their performance while reducing their market power. The economic insight behind this new evidence is that the waste recycling industry is constantly evolving and characterized by costly and technological investment, implying better performance for more specialized firms.

The digitalization of recycling companies encompasses all aspects of the business, including supplier and customer relationship management (as discussed in the paper), production process management, product innovation, data analysis, and quality control. Each of these business aspects represents a specific pathway through which digitalization positively influences performance metrics for recyclers, such as revenue, profits, and productivity. On one hand, the digitalization of customer services and quality control has direct effects on revenues by allowing for increased demand (Ingemarsdotter et al., 2020; Ranta et al., 2021). On the other hand, profits are more significantly impacted by the digitalization of production processes—such as the adoption of digital technology to classify and separate materials (Alonso et al., 2021)—as well as big data analysis and AI techniques, which enhance efficiency and reduce costs (Modgil et al., 2021; Bag et al., 2021). These considerations represent the starting point for future research plans investigating the specific ways in which the digitalization of recycling activities positively impacts various dimensions of performance. An exhaustive review of this emerging field of research was recently provided by Chauhan et al. (2022).

From the social point of view, we find that higher firm's performance in the recycling industry is associated to higher separate collection rate, regional governments characterized by a more conservative political ideology, and higher regional income.

Our empirical analysis can provide important policy insights. Policy makers should promote i) mergers, joint ventures, and network contracts among companies active in recycling, ii) digitization of production, transactions, and communication processes, ii)specialization, for instance by prioritizing subsidies for those recyclers who carry out recycling activities as both primary and secondary activity, iv). awareness campaigns for separate waste collection would reduce the amount of marine waste sent to landfills, providing a valuable incentive to increase investment in recycling activities.

Here follows some considerations and strategies for addressing potential limitations of our work, while also outlining future research directions.

When considering the representativeness of our outcomes with respect to other EU countries, it emerges that a potential limitation is the reliance on the Rae code, which is specific to the Italian context. This restricts the generalizability and replicability of our findings in other countries where different classification systems are used. Our study could benefit from further research in which the specialization variable may be linked to specific materials (e.g. packaging, chemical, metal, etc…). This aspect should be accounted for explicitly by considering the specific ATECO sub-group classification. Indeed, our empirical analysis serves as an initial phase of research, where the only distinction among recyclers lies in whether recycling is their primary or secondary business. Recycling is a very heterogeneous activity, since it may be focused on specific materials and characterized by international exchange of recyclable materials. These factors could influence markup and performance of recyclers, and should be considered in a second step of our research, in order to extend the analysis to scenarios where performance is not specific to the local context in which the recycler is located.

Another extension could involve examining the connections among the recycling systems of various regions and provinces through network analysis. This approach is particularly relevant given that the recycling market may not be entirely regional—especially for specialized firms on specific materials—and that performance may be influenced by factors of other regions.

We recognize that issues related to missing variables in our regression models can affect the validity and reliability of the results. For example, firm-level data concerning environmental certification would enhance the relevance of our research; however, such data is not available for a sample of firms as large as ours. Additionally, specific waste-related policies could offer valuable insights, although their effects may be partially captured by the variable of political ideology.

CRediT authorship contribution statement

Luca Correani: Writing – original draft, Software, Methodology, Data curation, Conceptualization. **Patrizio Morganti:** Writing – original draft, Methodology, Data curation, Conceptualization. **Ilaria Benedetti:** Writing – original draft, Supervision, Data curation. **Federico Crescenzi:** Writing – original draft, Supervision, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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