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Skills for the Circular Economy

Report on the sample survey on circular innovations in Emilia-Romagna and Veneto

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Summary

1. Introduction

In March 2020, the European Union launched the new Industrial Strategy to guide the green and digital transition and to enhance the resilience and competitiveness of European industrial ecosystems. This strategy was also incorporated into the European Green Deal, launched in December 2019, which provides a long-term growth agenda for Europe aimed at achieving climate neutrality across the continent by 2050. The main objective is to establish a fair ecological transition, entailing the collective adoption of circular production models and the integration of social measures to safeguard workers' rights, job opportunities, and the development of new skills (European Commission, 2020). The Circular Economy (CE) is an economic model designed to minimize waste and to valorise existing resources through a continuous cycle of use. In contrast to the traditional linear economy, which follows the "produce, use, dispose" pattern, the circular economy promotes the design of durable products and the repair, reuse, and recycling (3Rs) of materials.
This approach not only helps preserve the environment by reducing ecological impact but also offers innovative and sustainable economic opportunities. Implementing circular economy strategies can lead to greater resource efficiency, stimulate innovation, and create new "green" jobs.

In this transition the productive system has a key role, which must serve as a catalyst for change, growth, and innovation. A radical transformation of production technologies and business models, together with a restructuring of the industrial landscape, is essential to facilitate the shift from a linear to a circular economy.
Firms will need to rethink and develop new business models aligned with a circular approach—managing resources more efficiently and safely, extending their lifespan, reducing waste, and enabling reuse in new production processes. In this regard, the achievement of CE objectives is intrinsically linked to environmental innovation, understood as a regenerative process aimed at establishing new routines within production processes and rethinking final products.

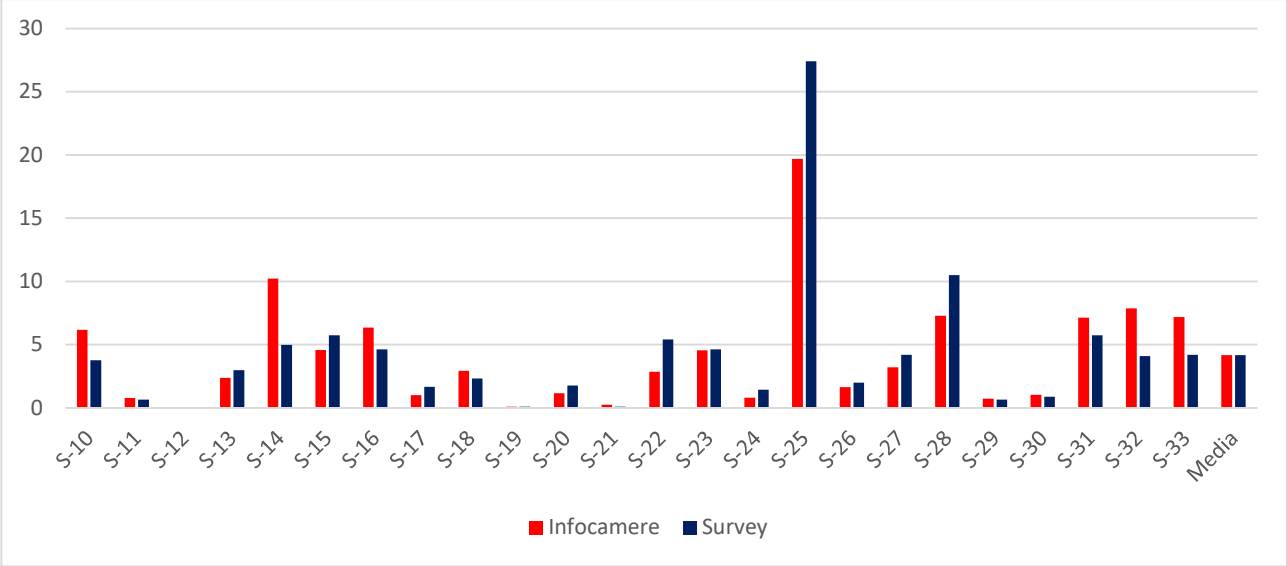
The survey on circular innovations in Emilia-Romagna and Veneto is among the main activities carried out within the project "GRINS – Growing Resilient, INclusive and Sustainable", Extended Partnership – Thematic Area 9 "Economic and financial sustainability of systems and territories", Spoke 5 "Innovation – Ecosystems for the Circular Economy", as part of the National Recovery and Resilience Plan (NRRP) – Mission 4 "Education and Research", Component 2 "From Research to Business", Investment 1.3, funded by the European Union – NextGenerationEU.
Through a CAWI/CATI survey, a valuable set of information was collected concerning the main characteristics of firms and their innovation strategies—particularly those oriented toward the principles of the circular economy—as well as their use of digital and Industry 4.0 technologies.
In addition, a specific section of the questionnaire focuses on the impact of the COVID-19 pandemic on firms and their responses to it. The survey was conducted by the company IZI S.p.A. between October and November 2023 and covers the years 2020, 2021, and 2022.
The final sample includes 1,549 firms, of which 644 (41.58%) are in Emilia-Romagna and 905 (58.42%) in Veneto.

2. Sampling

The initial population of active firms was extracted from the Chamber of Commerce database, using firm size (classified by employee numbers), sector (two-digit ATECO classification), and geographical location within the two regions of interest, Emilia-Romagna and Veneto, as stratification criteria. From an initial population of 19,534 firms, a final sample of 1,549 firms was obtained, with a response rate of approximately 8%.

Graphs 2.1 and 2.2 show the comparison between the distribution of responding firms and the distribution provided by Infocamere, which reports the number of active firms by region and sector for the year 2020. The comparison is conducted for both Veneto and Emilia-Romagna, using the two-digit ATECO classification[1].

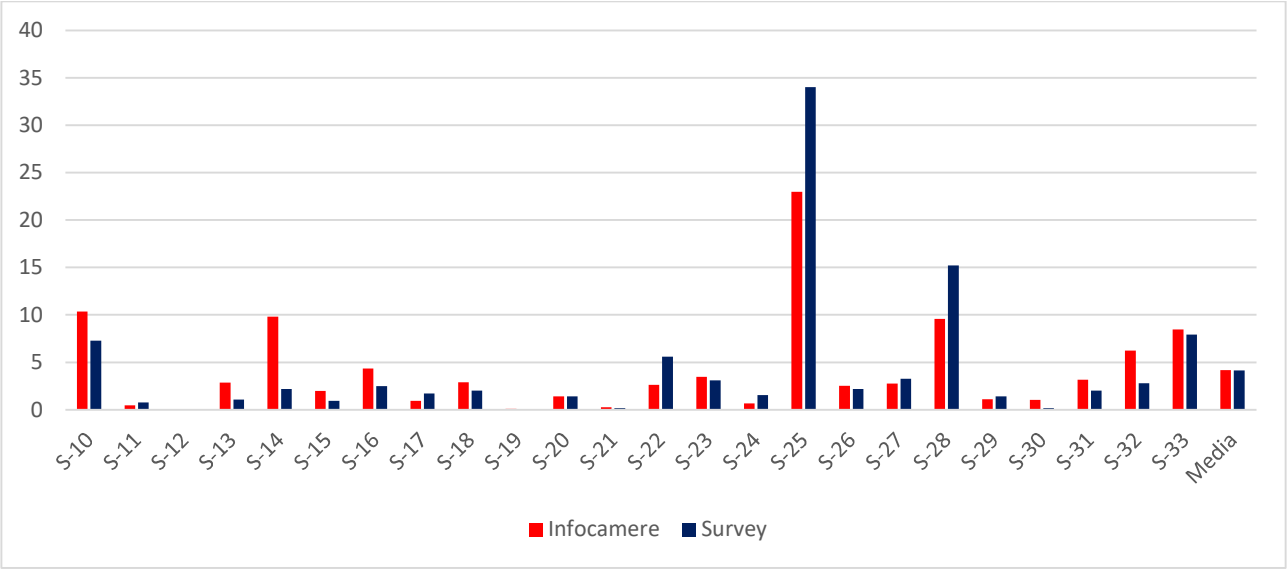
Graph 2.1 – Distribution of enterprises by sector: Veneto



Except for the clothing sector (S-14) and other manufacturing industries (S-33), where the share of sampled firms is significantly lower than the existing population, as well as for the manufacture of metal products (S-25) and machinery (S-28), where the sampled share is significantly higher, the difference in frequency does not exceed three percentage points. On average, the analysed sample of firms from Veneto is perfectly aligned with the existing population as of 2020

[1] In the appendix, Tables A1 and A2 report the percentages of firms by sector for Veneto and Emilia-Romagna, respectively.

Graph 2.2 – Distribution of enterprises by sector: Emilia-Romagna



Except for the food sector (S-10) and clothing sector (S-14), where the share of sampled firms is significantly lower than the existing population, as well as for the manufacture of metal products (S-25) and machinery (S-28), where the sampled share is significantly higher, the difference in frequency does not exceed three percentage points. On average, the analysed sample of firms from Emilia-Romagna is perfectly aligned with the existing population as of 2020.

3. The Survey

After briefly illustrating the degree of representativeness of the analysed sample, this section presents the main information that can be derived from the survey.
In the following subsections, the two regions are compared across different dimensions:
(1) firm characteristics, (2) technological innovation, (3) circular innovation, and (4) the effects of COVID-19.

3.1 Characteristics of enterprises

Tables 3.1 and 3.2 show the distribution of responding firms by province in Veneto and Emilia-Romagna, respectively. In Veneto, the largest number of respondents is concentrated in the provinces of Vicenza, Treviso, and Padua, which together represent 72.59% of all surveyed firms in the region.

In Emilia-Romagna, the distribution appears more heterogeneous across regions, with Modena, Bologna, and Reggio Emilia together accounting for 59.46% of the total.

Table 3.1 Distribution of respondents by province: Veneto

NUTS3 region	Frequency
Belluno	2.87%
Padua	21.99%
Rovigo	3.31%
Treviso	23.31%
Venice	9.06%
Vicenza	27.29%
Verona	12.15%

Table 3.2 Distribution of respondents by province: Emilia-Romagna

NUTS3 region	Frequency
Bologna	17.08%
Ferrara	5.43%
Forlì	9.94%
Modena	25.77%
Piacenza	5.43%
Parma	8.07%
Ravenna	5.59%
Reggio Emilia	16.61%
Rimini	6.06%

Tables 3.3 and 3.4 show the distribution of firms by ATECO two-digit sector in Veneto and Emilia-Romagna, respectively. In Veneto, the largest sectors in terms of firm numbers are Sector 25 – Manufacture of fabricated metal products (except machinery and equipment) and Sector 28 – Manufacture of machinery and equipment N.E.C., accounting for 27.4% and 10.5%, respectively.
The remaining sectors show shares ranging from 0.1% to 6%.
Similarly, in Emilia-Romagna, the most represented sectors are 25 (34.01%) and 28 (15.22%), while the remaining sectors range between 0.16% and 8%.

Table 3.3 Distribution of respondents by ATECO 2-digit sector, Veneto[2].

ATECO	Freq (%)	ATECO	Freq (%)	ATECO	Freq (%)
10 - Food industry	3.76	19 – Manufacture of coke and products derived from petroleum refining	0.11	27 – Manufacture of electrical equipment and non-electrical household appliances	4.20
11 - Beverage industry	0.66	20 – Manufacture of chemical products	1.77	28 – Manufacture of machinery and equipment n.e.c.	10.50
13 - Textile industries	2.98	21 – Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.11	29 – Manufacture of motor vehicles, trailers and semi-trailers	0.66
14 - Manufacture of clothing; manufacture of leather and fur goods	4.97	22 – Manufacture of rubber and plastic products	5.41	30 – Manufacture of other transport equipment	0.88
15 - Manufacture of leather and related products	5.75	23 – Manufacture of other non-metallic mineral products	4.64	31 – Furniture manufacturing	5.75
16 – Wood and wood and cork products industry (excluding furniture); manufacture of straw and plaiting materials	4.64	24 – Metallurgy	1.44	32 – Other manufacturing industries	4.09
17 – Manufacture of paper and paper products	1.66	25 – Manufacture of metal products (excluding machinery and equipment)	27.40	33 – Repair, maintenance and installation of machinery and equipment	4.20
18 – Printing and reproduction of recorded media	2.32	26 – Manufacture of computers and electronic and optical products; electromedical apparatus, measuring apparatus and watches	1.99	45 – Wholesale and retail trade; repair of motor vehicles and motorcycles	0.11

[2] For the same distribution at the 3-digit ATECO code level, see Table A3 in the Appendix.

Table 3.4 Distribution of respondents by ATECO 2-digit sector, Emilia-Romagna[3].

ATECO	Freq (%)	ATECO	Freq (%)	ATECO	Freq (%)
10 - Food industry	7.30	21 – Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.16	30 – Manufacture of other transport equipment	0.16
11 - Beverage industry	0.78	22 – Manufacture of rubber and plastic products	5.59	31 – Furniture manufacturing	2.02
13 - Textile industries	1.09	23 – Manufacture of other non-metallic mineral products	3.11	32 – Other manufacturing industries	2.80
14 - Manufacture of clothing; manufacture of leather and fur goods	2.17	24 – Metallurgy	1.55	33 – Repair, maintenance and installation of machinery and equipment	7.92
15 - Manufacture of leather and related products	0.93	25 – Manufacture of metal products (excluding machinery and equipment)	34.01	46 – Wholesale trade (excluding motor vehicles and motorcycles)	0.31
16 – Wood and wood and cork products industry (excluding furniture); manufacture of straw and plaiting materials	2.48	26 – Manufacture of computers and electronic and optical products; electromedical apparatus, measuring apparatus and watches	2.17	47 – Retail trade (excluding motor vehicles and motorcycles)	0.16
17 – Manufacture of paper and paper products	1.71	27 – Manufacture of electrical equipment and non-electrical household appliances	3.26	62 – Software production, IT consultancy and related activities	0.16
18 – Printing and reproduction of recorded media	2.02	28 – Manufacture of machinery and equipment n.e.c.	15.22	74 – Other professional, scientific and technical activities	0.16
20 – Manufacture of chemical products	1.40	29 – Manufacture of motor vehicles, trailers and semi-trailers	1.40		

Table 3.5 reports the percentages of firms according to several characteristics related to ownership structure, management composition, market positioning, and quality certification. Almost half of the sample consists of family-owned firms, and about 40% have at least one woman among their top

[3] For the same distribution considering the 3-digit ATECO codes, see Table A4 in the appendix.

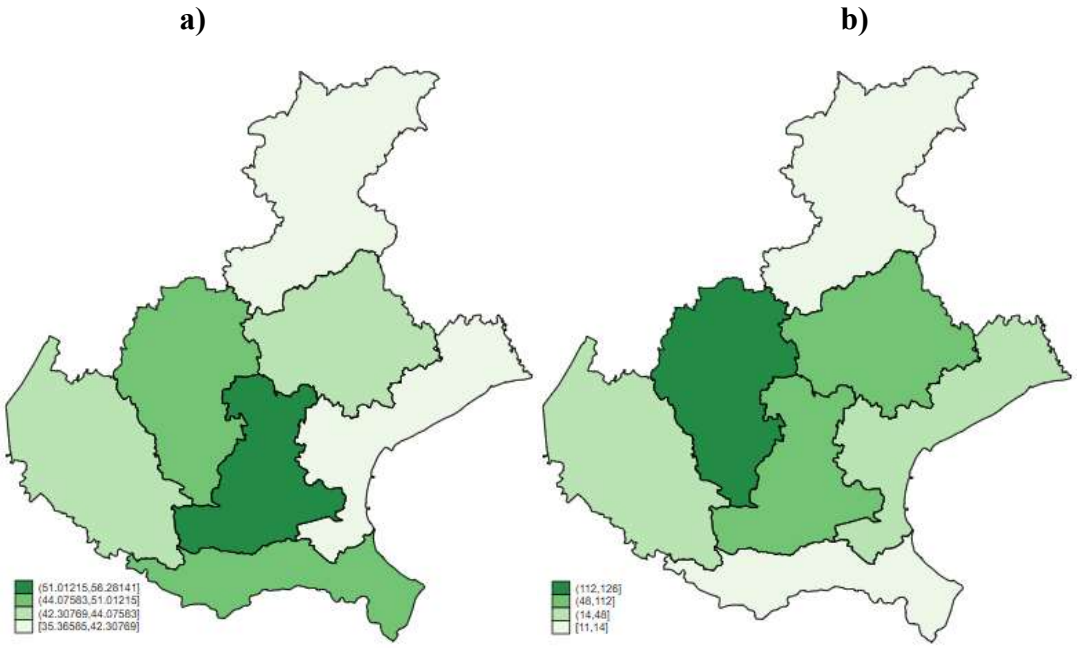
management positions. The presence of young managers under 35 and/or non-graduate managers is less frequent (around 15%). Regarding market positioning, approximately 15% of firms belong to an industrial group and/or a production chain, while a smaller share is part of an industrial district or a formal business network. Finally, it is noteworthy that about 50% of firms (with a slightly higher share in Veneto) operate in foreign markets through export activity and hold at least one quality certification (such as ISO 9001, ISO 14011, ISO 45001, SA 8000).

Table 3.5 Firm characteristics.

	VENETO	EMILIA-ROMAGNA
Family-run companies	48.40%	42.70%
Companies with at least one woman in a management position	40.22%	36.18%
Companies with at least one manager under the age of 35	16.35%	15.06%
Companies with at least one manager without a degree	71.71%	69.1%
The company is part of a group	14.14%	14.91%
The company is part of a supply chain	14.14%	14.75%
The company is part of a district	7.96%	6.99%
The company has entered into a network contract	5.3%	5.59%
The company is an exporter	54.03%	43.48%
Companies with at least one quality certificate	47.85%	45.5%

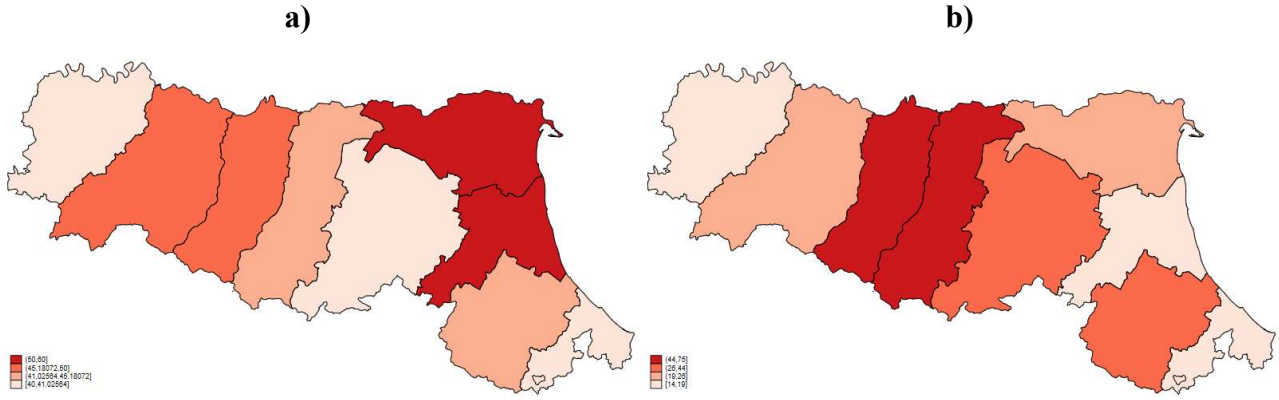
Figure 3.1 illustrates the geographical distribution, by province, of the share (a) and absolute number (b) of firms holding at least one quality certification. The highest percentage is recorded in Padua, while the highest absolute number of certified firms is found in Vicenza.

Figure 3.1 Firms with at least one quality certification: share (a) and absolute values (b) – Veneto



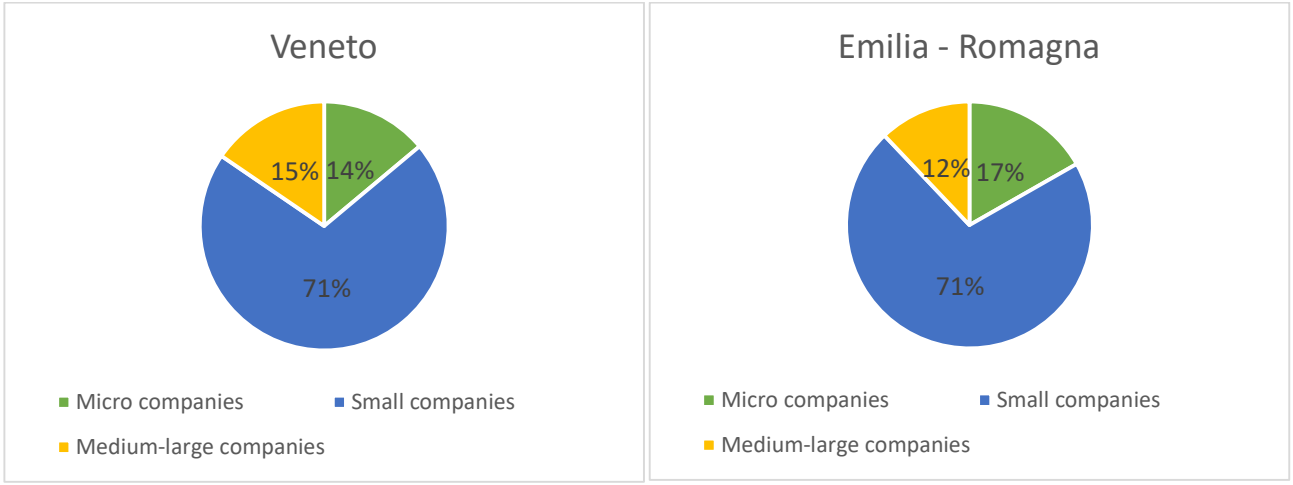
The Emilia-Romagna framework is illustrated in Figure 3.2. The provinces with the highest percentages (a) are Ferrara and Ravenna, followed by Parma and Reggio Emilia, while those with the highest absolute number of certified companies (b) are Reggio Emilia and Modena, followed by Bologna and Forlì–Cesena.

Figure 3.2 – Firms with at least one quality certification: share (a) and absolute values (b) – Emilia-Romagna



Graph 3.1 shows the distribution of the sampled companies by size, based on the number of employees. In Veneto, small companies (between 10 and 50 employees) predominate among the responding enterprises, accounting for 71%, while micro-enterprises (fewer than 10 employees) and medium-large enterprises (50 or more employees) account for 14% and 15% respectively. The composition in Emilia-Romagna is very similar, but in this case, micro-enterprises (17%) prevail over medium-large enterprises (12%).

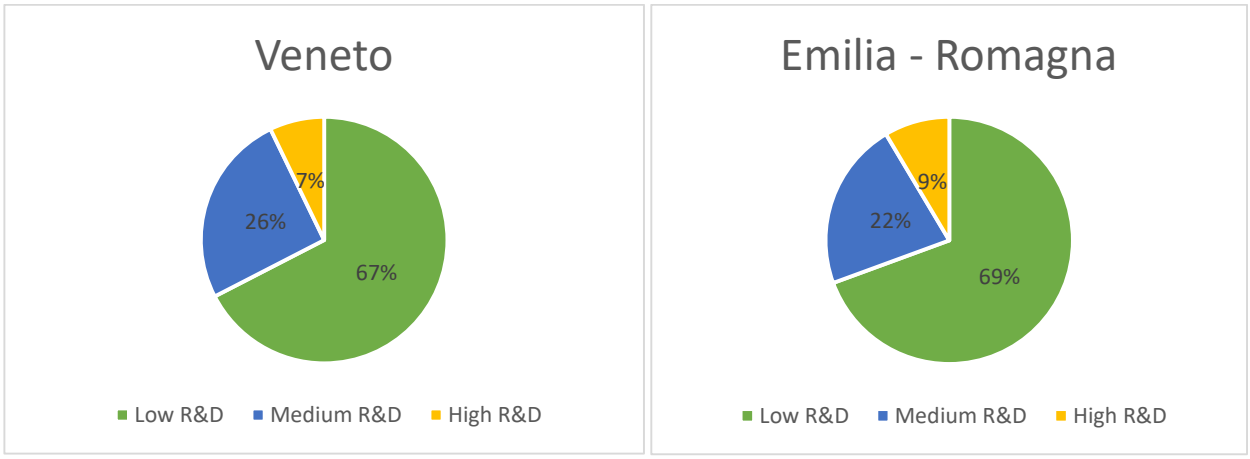
Graph 3.1 Firm size in terms of employees in 2020-2022



Among employees, particular attention is paid to those involved in Research and Development (R&D) activities. Graph 3.2 shows the distribution of companies based on the share of employees

working in R&D, calculated as an average over the three-year period 2020-2022. The chart identifies three groups of companies: (i) low-R&D companies are those with an average share of R&D employees of less than 5%; (ii) medium R&D companies include those with a share of between 5% and 20%; and finally (iii) high-R&D companies include those with a share of 20% or more. The graph shows that there are no major differences between Veneto and Emilia-Romagna: in both cases, around 70% of companies fall into the low R&D group, between 20% and 25% of companies fall into the medium R&D group, and just under 10% of companies are in the high R&D group.

Graph 3.2 Level of R&D based on the share of employees in 2020-2022



3.2 Technological innovation

The following section summarises the responses provided by companies regarding their technological innovation activities, reporting various information on the types of innovation, timing, investments made, obstacles encountered, and entities with which some form of collaboration has been established. The next section will refer specifically to innovations in the field of the circular economy.

Table 3.6 shows the percentages of innovative companies by type of innovation. In both regions, there is a slight prevalence of product-innovating companies, which is more evident in Emilia-Romagna, although, in general, no specific type of innovation seems to prevail markedly over the others.

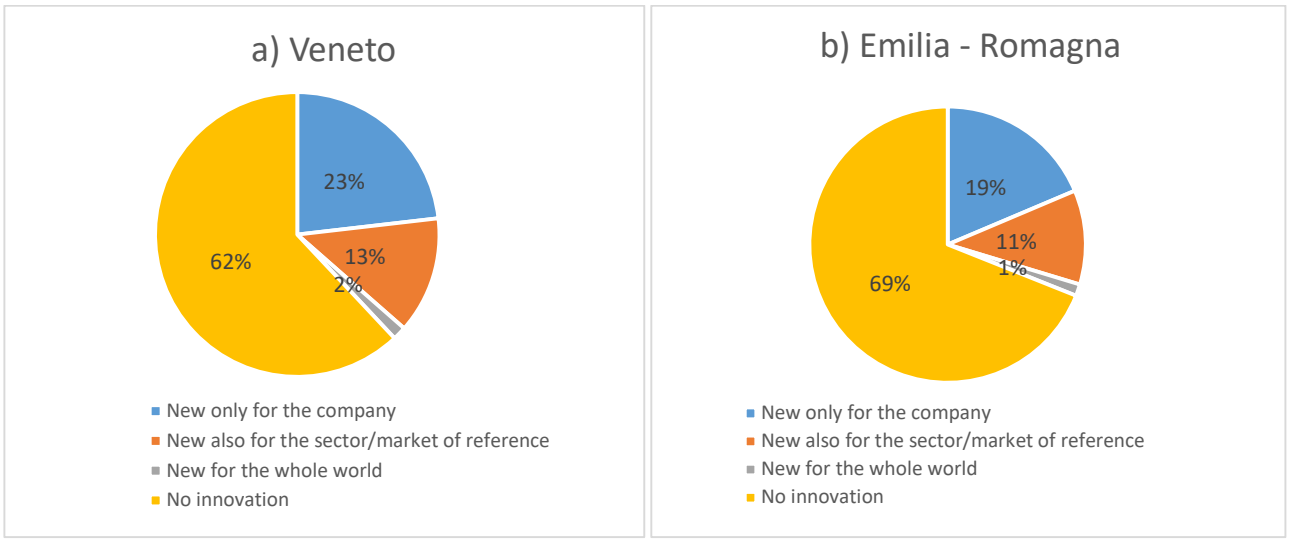
Table 3.6 Share of innovative firms

Type of innovation	VENETO	EMILIA-ROMAGNA
Product	38.01%	31.10%
Process	37.90%	33.39%
Organisational	33.26%	29.81%

Graph 3.3 shows the distribution of product-innovating firms by degree of product innovation, i.e., whether (i) new only to the company, (ii) new to the sector, or (iii) new to the world.

As might be expected, most product innovations are incremental in nature, i.e., new to the company (around 20%), while the most radical innovations involving products that are new to the sector or to the world as a whole account for 11-13% and 1-2% of cases, respectively.

Graph 3.3 Product innovations by degree of novelty



Looking at the geographical distribution of innovative companies, Figure 3.3 shows that, for the Veneto region, the highest share belongs to the province of Belluno, followed by Padua and Vicenza, while if we look at the total number of innovative companies, the province of Vicenza prevails, followed by Padua and Treviso.

Figure 3.3 Firms that have introduced innovations, shar (a) and absolute values (b) - Veneto

a) **b)**

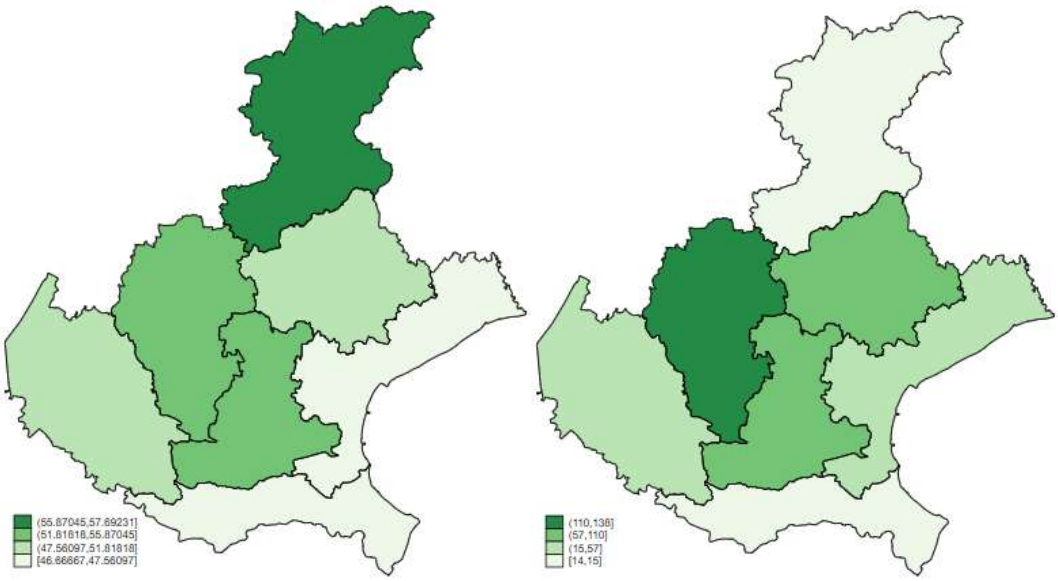
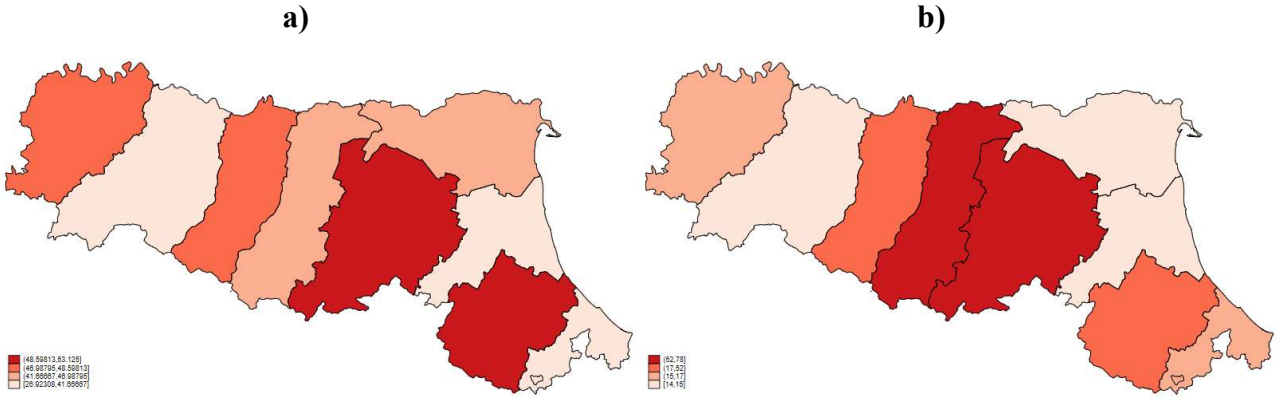


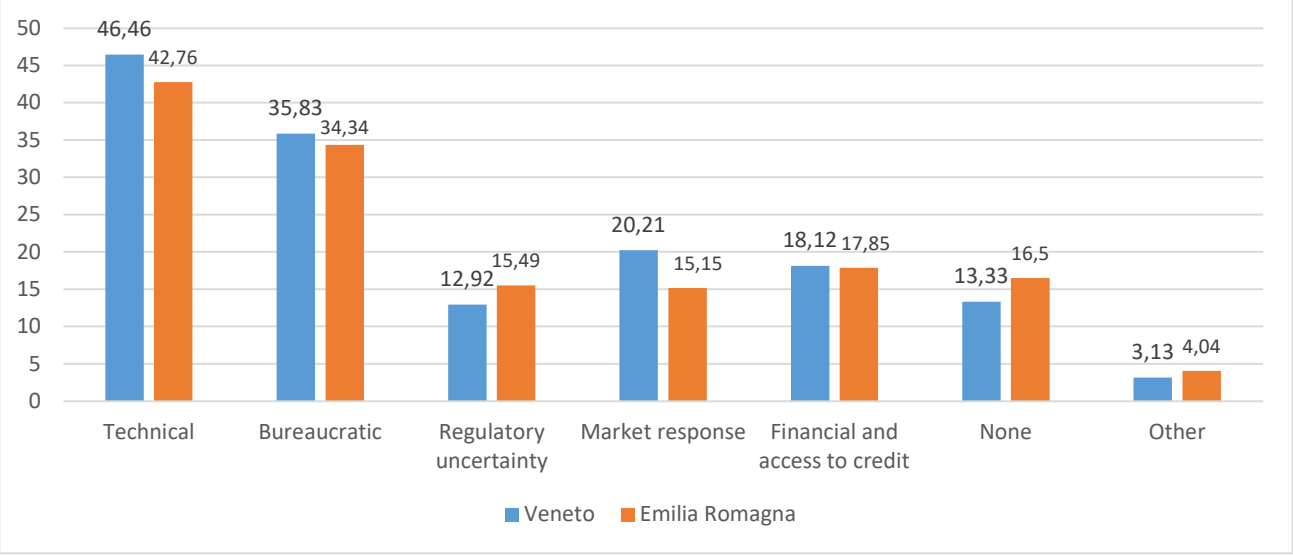
Figure 3.4 shows the same distributions for Emilia–Romagna. In this case, map (a) indicates that the highest percentages are in the provinces of Bologna and Forlì–Cesena, followed by Piacenza and Reggio Emilia, while the highest number of innovative enterprises is recorded in the provinces of Bologna and Modena, followed by Reggio Emilia and Forlì–Cesena.

Figure 3.4 Firms that have introduced innovations, share (a) and absolute values (b) - Emilia-Romagna



Graph 3.4 shows what companies consider to be the obstacles to innovation. In both regions, the main obstacles encountered are technical and bureaucratic in nature. It can also be seen that in Veneto, market response is considered an obstacle by a greater number of businesses, 20.21% compared to 15.15% in Emilia-Romagna. In the latter, there is also a higher percentage of firms that have not encountered obstacles to innovation, 16.5% compared to 13.33% in Veneto

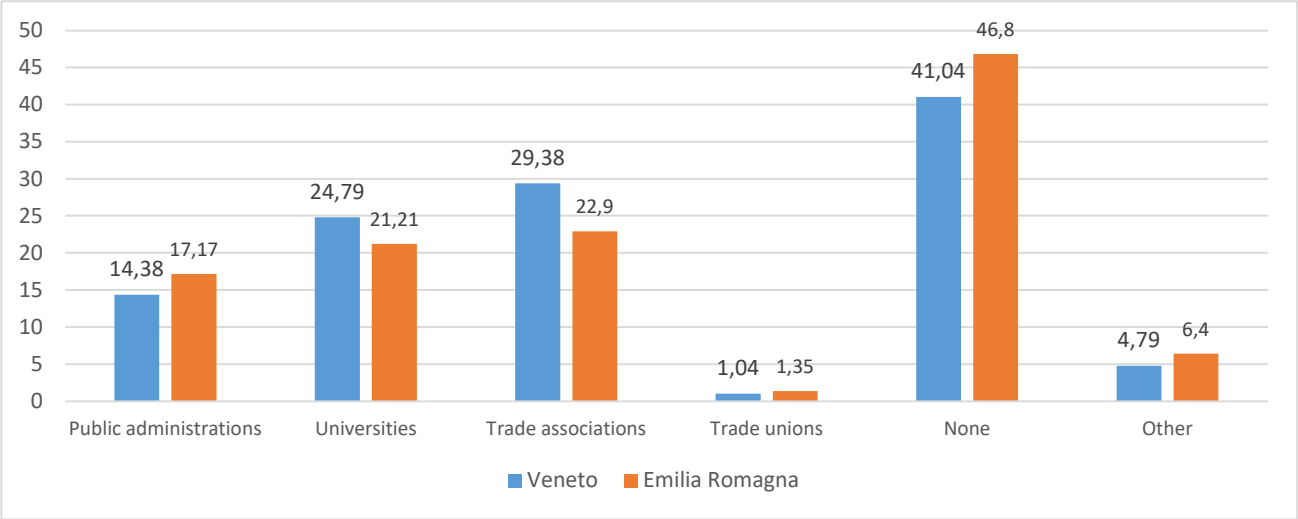
Graph 3.4 Obstacles to innovation [4]



[4] In Graphs 3.4, 3.5, 3.6, and 3.7, the denominator used in calculating the percentages is the number of enterprises that have introduced at least one product, process, or organisational innovation, i.e., 480 for Veneto and 297 for Emilia-Romagna.

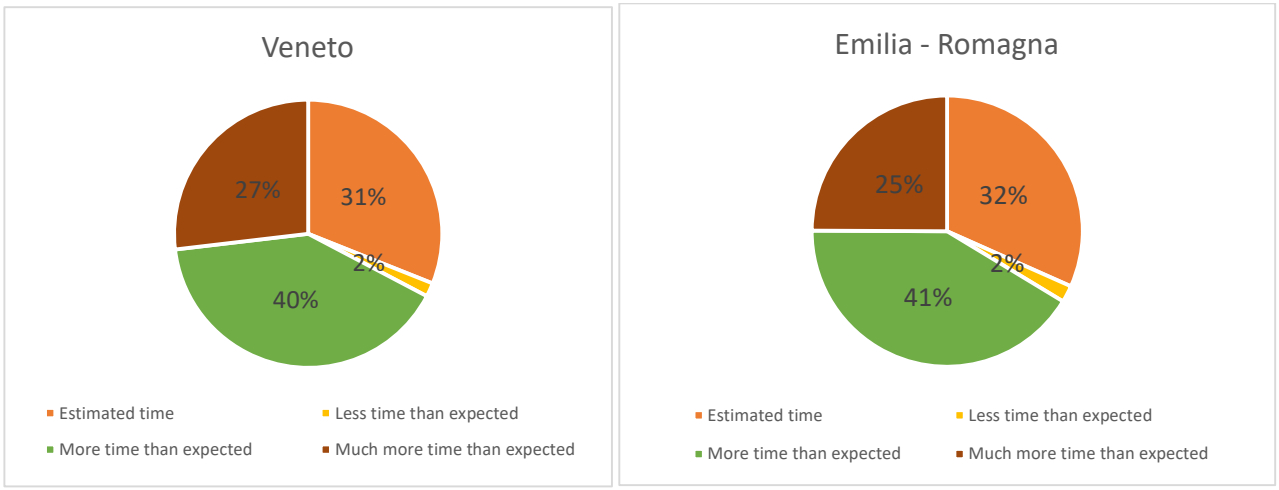
In addition to obstacles to innovation, the responding companies also reported which entities they had established forms of collaboration with or from which they had received support during the innovation process. Graph 3.5 reveals that, in Emilia-Romagna, there is a greater propensity to collaborate with public administrations than in Veneto. If we look at relations with universities and trade associations, however, Veneto reports significantly higher percentages than its neighbouring region. In both regions, however, trade unions do not seem to represent a source of support for innovation, with percentages not even reaching 2%. It is interesting to note, however, that the highest percentage is recorded for companies that do not collaborate at all with other entities during the innovation process, with values above 40% in both regions.

Graph 3.5 Organisations useful for comparison/support during the innovation process



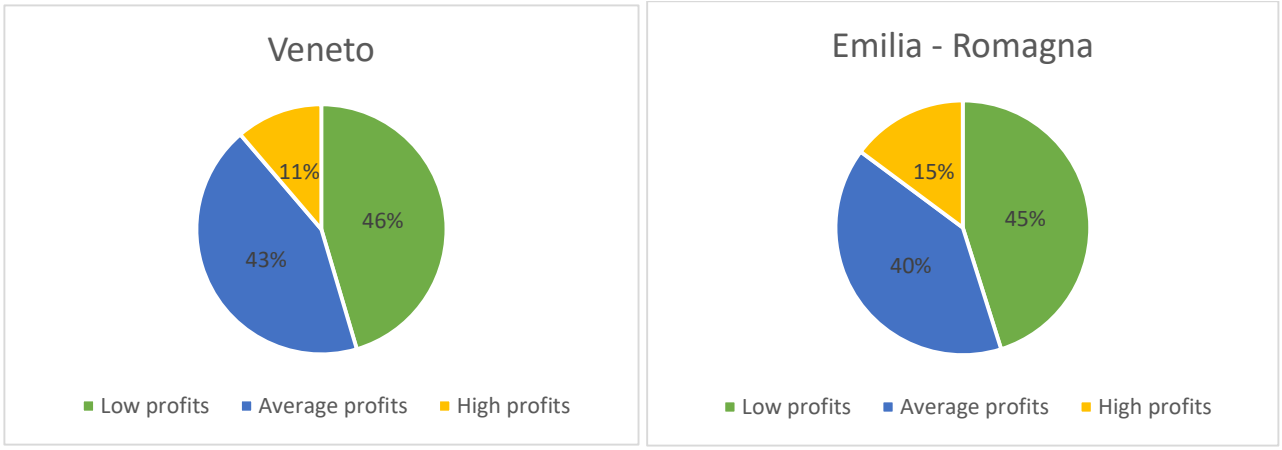
Graph 3.6 refers to the timing of the innovation process. The questionnaire submitted to companies included four possible answers: 1) “Estimated time”, 2) “Less time than expected”, 3) “More time than expected”, and 4) “Much more time than expected”. The graph shows that the differences between the two regions are minimal and that, in general, companies take longer than estimated, with a cumulative percentage of companies of over 65% for both regions if we consider the answers to points 3 and 4 together. A significant proportion, around 30%, still manage to stay within the estimated time frame, and, in rare cases (2%), the time frame is shorter than expected.

Graph 3.6 Innovation timelines



Graph 3.7 refers to the 2020-22 average of the share of profits deriving from product innovation. Three categories were considered in this regard: 1) "low profits" if the share is less than 5%, 2) "medium profits" if the share is between 5% and 20%, and 3) "high profits" if the share is equal to or greater than 20%. In both regions, the prevailing cases are "low profits" and "medium profits": in both regions, the percentages of companies belonging to these two categories vary between 40% and 46%. In the case of Veneto, 11% of companies recorded a share of profits from product innovations greater than 20%, while for Emilia-Romagna, the percentage rises to 15%

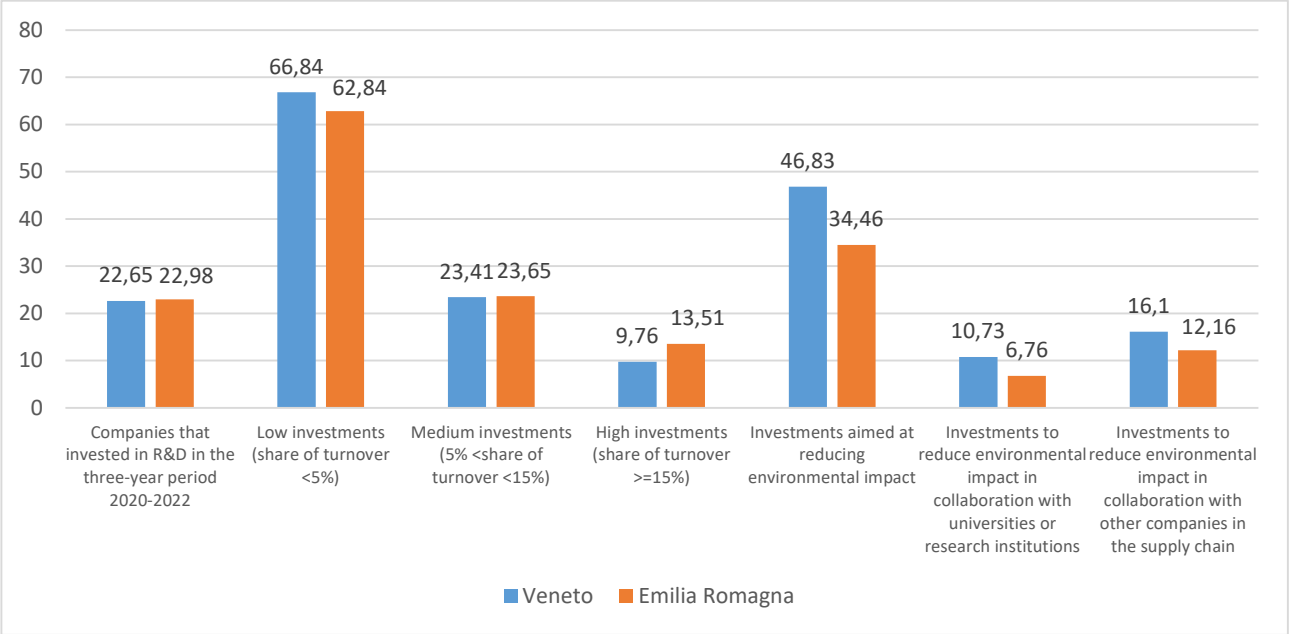
Graph 3.7 Share of profits deriving from product innovations



An overview of R&D investments is provided in Chart 3.8. The percentage of companies that invested in R&D in the two regions is similar, at around 23%. However, there is a slight difference in the amount of investment made. We can see that the two regions have a similar percentage of firms, around 23%, whose investments as a percentage of turnover are between 5% and 15%. Veneto has a higher percentage of firms that report having made "low investments", while Emilia-Romagna has a higher percentage of firms that report having made "high investments" (share of turnover exceeding 15%). Looking at the purpose of R&D, we note that the frequency of companies that focus their R&D

activities on reducing the environmental impact of production processes is higher in Veneto (approximately 47%) than in Emilia-Romagna (approximately 34%), whether the companies collaborate with universities or research centres or with other companies in the supply chain.

Graph 3.8 Investment in R&D



To complete the overview of R&D, Figures 3.5 and 3.6 show the relative and absolute distribution of firms that invested in R&D in 2020-22 for Veneto and Emilia-Romagna, respectively. In Veneto, the region with the highest share of companies that invested in R&D is Verona, followed by Vicenza and Belluno. In absolute terms, instead, the leading region is Vicenza, followed by Padua and Treviso. In Emilia-Romagna, on the other hand, the regions with the highest share of firms that invested in R&D are Bologna and Ravenna, followed by Reggio Emilia and Modena. In absolute terms, Bologna remains among the top regions, together with Modena, Reggio Emilia, and Forlì-Cesena.

Figure 3.5 Firms investing in R&D in 2020-2022, share (a) and absolute number (b) - Veneto

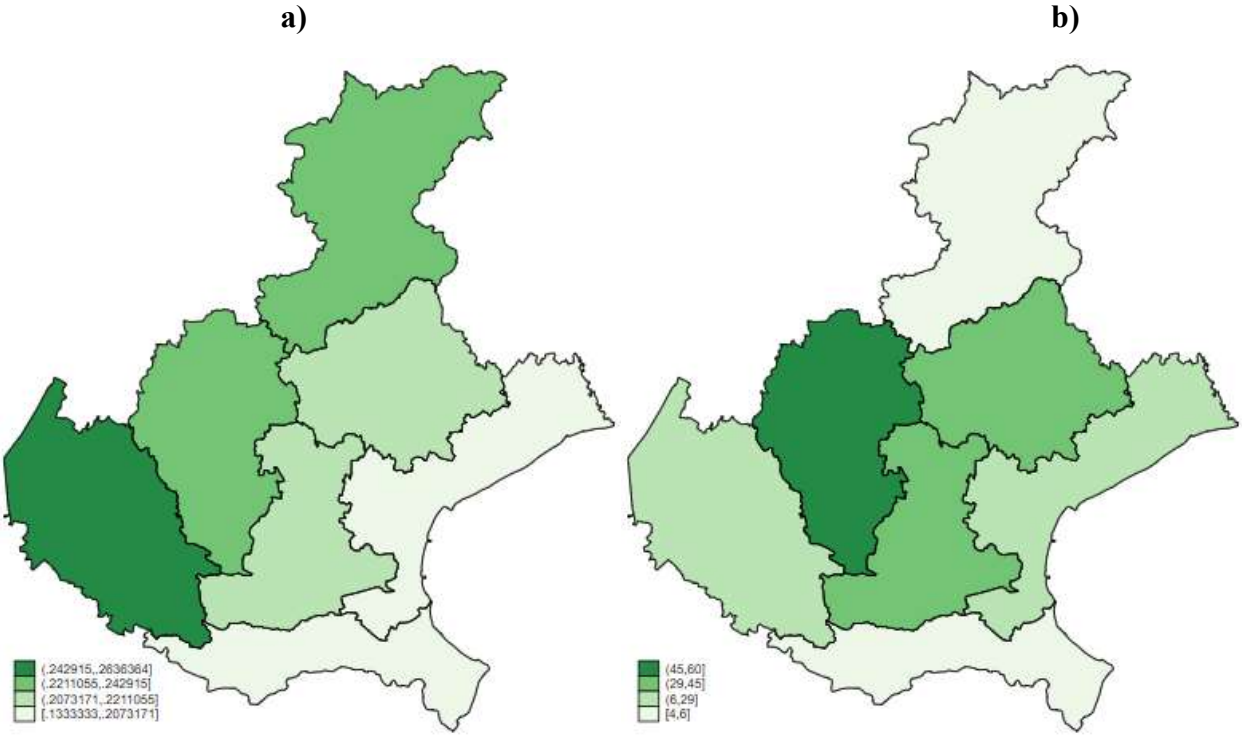
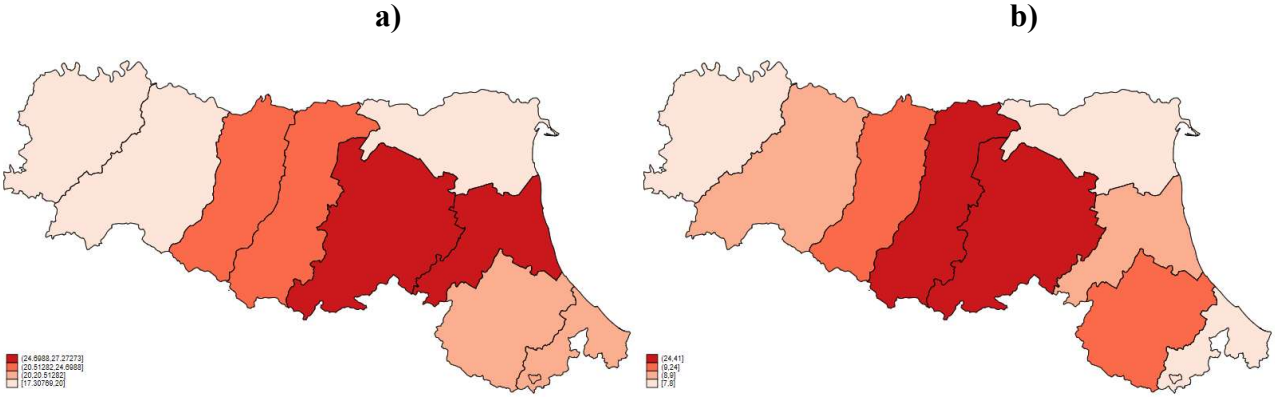


Figure 3.6 Firms investing in R&D in 2020-2022, share (a) and absolute number (b) – Emilia-Romagna



A natural outcome of R&D activity is patenting, which aims to protect the intellectual property rights associated with new products or processes invented by companies. In the following analysis, we focus on the number of patents filed in the three years 2020-2022 by the companies surveyed. Table 3.7 shows that Veneto has higher values both in terms of the number of companies that have applied for or filed patents and in terms of the average number of patents and, specifically, patents aimed at

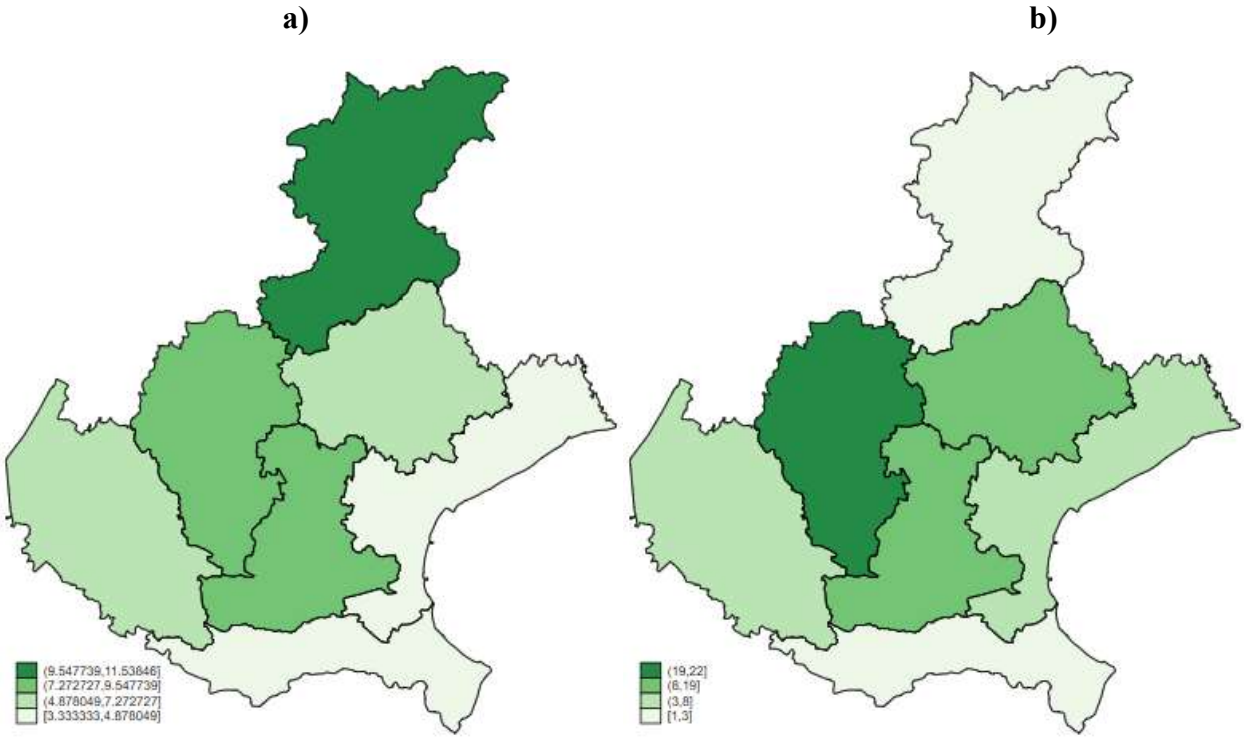
mitigating environmental impact. The latter difference is not surprising: in Graph 3.9, we had already noted that Veneto companies are more inclined to invest in "green" R&D than companies in Emilia-Romagna.

Table 3.7 Patents in 2020-2022[5]

	VENETO	EMILIA-ROMAGNA
Patent application or filing	7.96%	6.68%
Average number of patents filed	2.96	2.33
Average number of patents filed to reduce environmental impact	0.43	0.19

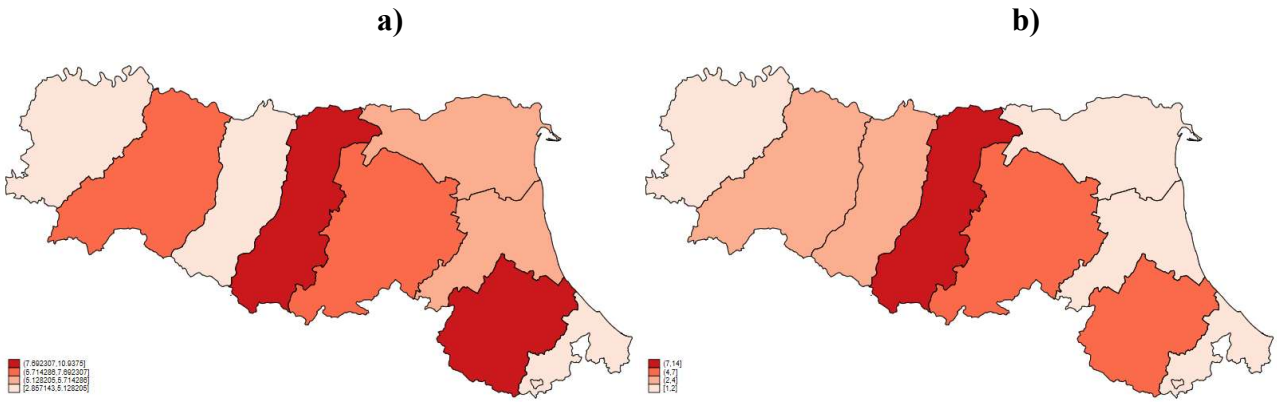
Figure 3.7 shows the geographical distribution of companies that have applied for or filed patents in Veneto. In percentage terms, the province of Belluno stands out in panel (a), followed by Vicenza and Padua, while if we look at the absolute number of patenting companies per province, panel (b), the province with the highest value is Vicenza, followed by Padua and Treviso.
Figure 3.8 shows the similar distribution for Emilia-Romagna. In panel (a), the leading provinces in percentage terms are Bologna and Ravenna, followed by Parma and Modena, while in panel (b), the provinces with the highest number of patenting companies are Bologna and Modena.

Figure 3.7 Firms applying for or filing patents in 2020-22, share (a) and absolute number (b) - Veneto



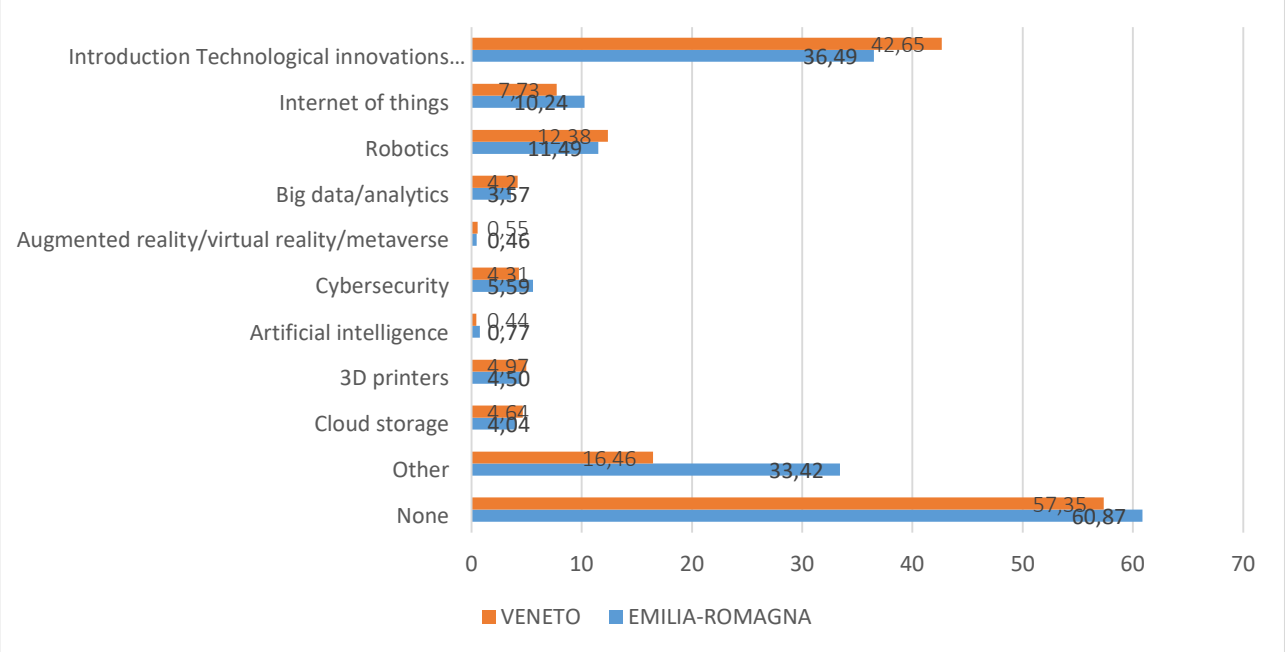
[5] The averages for patents filed are calculated only for companies that have declared that they have applied for or filed patents.

Figure 3.8 Firms applying for or filing patents in 2020-22, share (a) and absolute number (b) – Emilia-Romagna



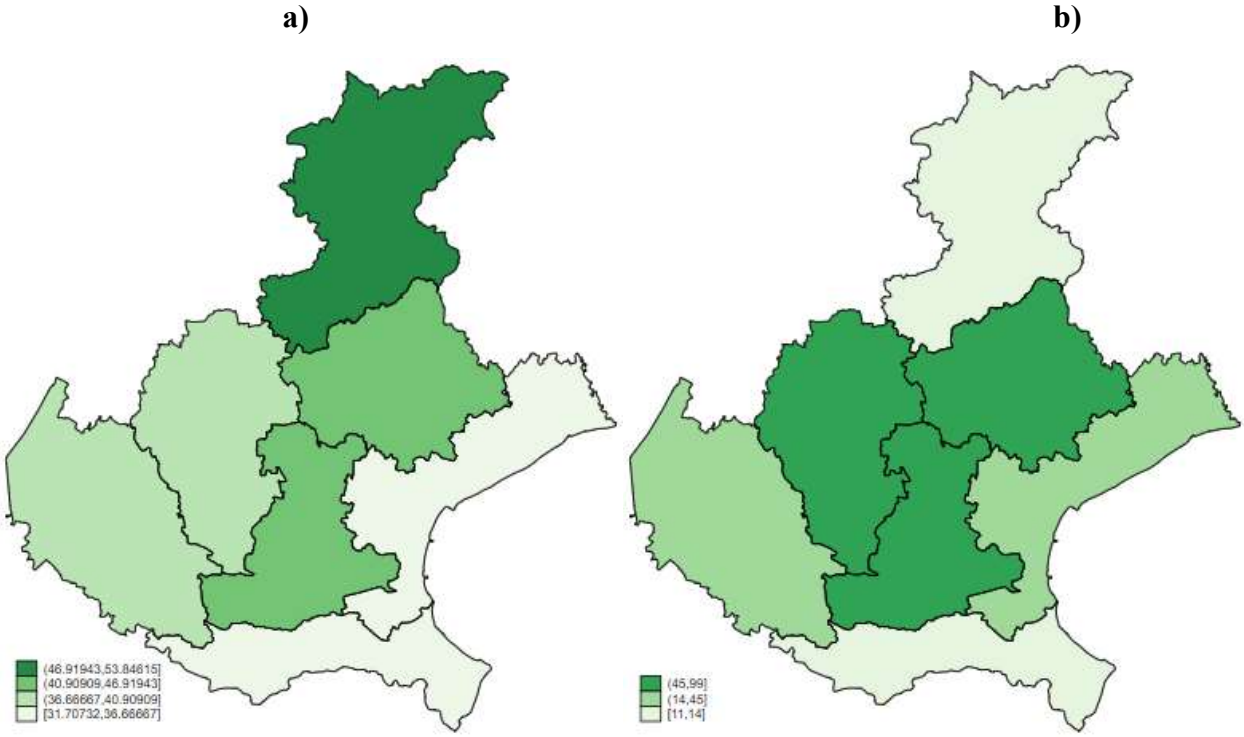
The last section before addressing the topic of circular innovations concerns the use of enabling technologies, i.e., those technologies linked to the Industry 4.0 paradigm. These technologies include the Internet of Things (IoT), Artificial Intelligence (AI), the cloud, 3D printing, augmented reality, cyber security, big data, and robotics. Graph 3.9 shows which 4.0 enabling technologies were adopted by our sampled firms between 2020 and 2022. The introduction of technological innovations associated with the Industry 4.0 transition occurred in 42.65% of firms in Veneto and 36.49% in Emilia-Romagna. Consequently, most surveyed firms reported that they had not adopted any new enabling technologies during the three years. In Veneto, the main technologies adopted or acquired were robotics (12.38%) and the Internet of Things (IoT) (7.73%), as well as other technologies not included in the predefined categories (16.46%). In Emilia-Romagna, firms likewise focused on IoT (10.24%) and, to an even greater extent than in Veneto, on other technologies not listed (33.42%), while robotics was the most widely adopted technology over the three years (11.49%).

Graph 3.9 Use of or investment in enabling technologies for Industry 4.0



The histogram in Figure 3.9 shows the percentage of firms that have used or invested in 4.0 technologies in the three-year period 2020-2022. Belluno shows the highest share, followed by Treviso and Padua, while the regions with the highest absolute numbers are Vicenza, Padua, and Treviso.

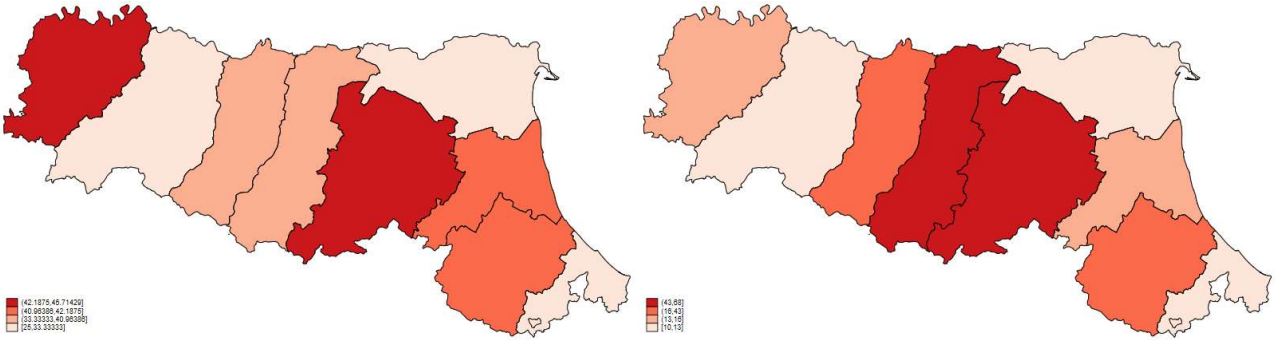
Figure 3.9 Firms that used or invested in 4.0 technologies in 2020-2022, share (a) and absolute terms (b) - Veneto



Concerning Emilia–Romagna, box (a) in Figure 3.10 shows that the provinces that have used or invested most in enabling technologies in percentage terms are mainly Piacenza and Bologna, but also Ravenna and Forlì–Cesena. If we look at the absolute values (box b), the provinces of Bologna and Modena stand out again, followed by Reggio Emilia and Forlì-Cesena. As with the other innovation indicators, the provinces with the lowest frequency of enterprises are Ferrara and Rimini.

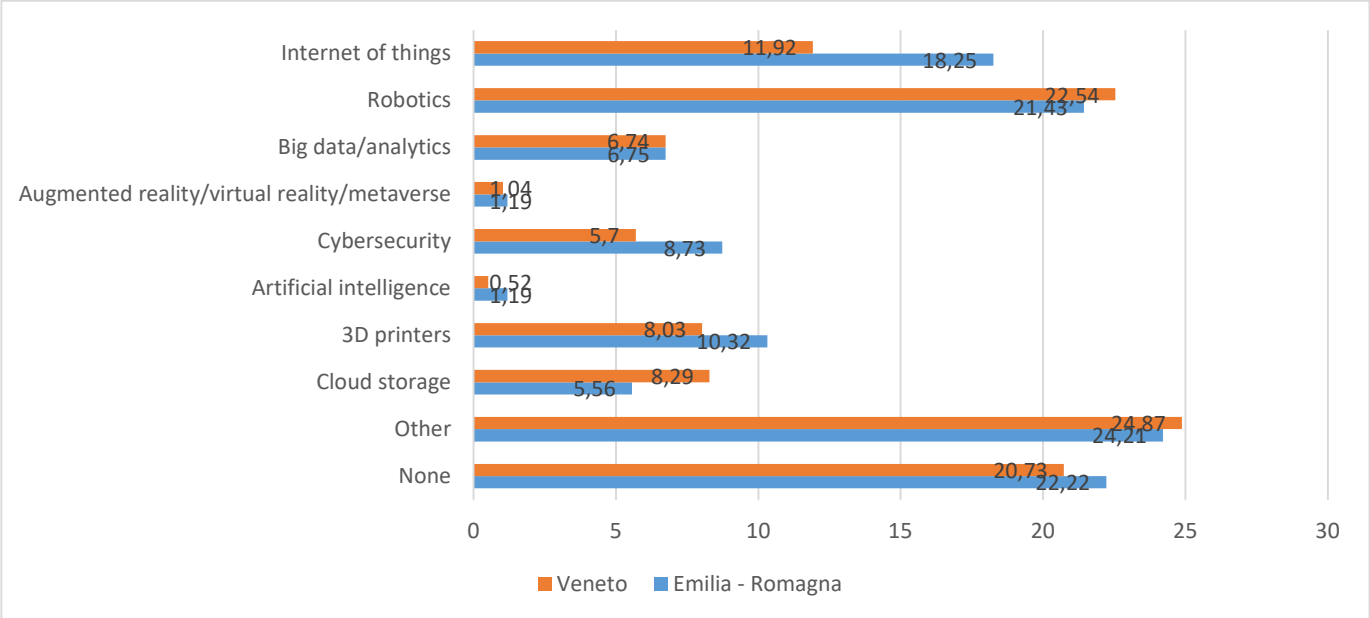
Figure 3.10 Firms that used or invested in 4.0 technologies in 2020-2022, share (a) and absolute terms (b) – Emilia-Romagna

a) **b)**



Finally, Graph 3.10 shows which companies had already introduced enabling technologies before the 2020-2022 three-year period[6]. In Veneto, the technologies with the highest percentages are IoT (11.92%), robotics (22.54%), and technologies considered in the "other[7]" category (24.87%), which do not differ significantly from the results seen previously in Figure 3.9. In Emilia-Romagna, we see high percentages for IoT technologies (18.25%), robotics (21.43%), 3D printing (10.32%) and those considered "other" (24.21%): robotics and 3D printing, therefore, seem to have lost their appeal in favour of other technologies, in particular "cloud storage", which shows a particularly high percentage in Graph 3.9.

Graph 3.10 Introduction of 4.0 technologies before 2020-2022



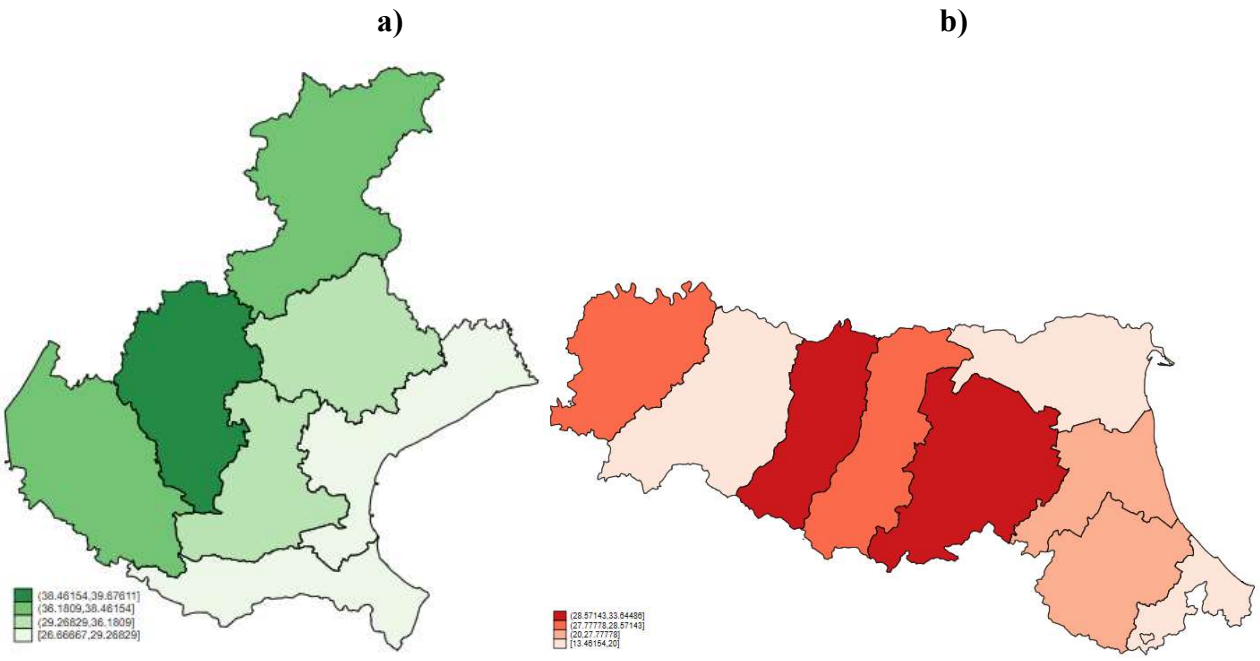
[6] In Graph 3.11, the percentages are calculated in relation to the number of companies that responded that they had introduced enabling technologies in the three-year period 2020-2022, i.e. 386 for Veneto and 252 for Emilia-Romagna.
[7] Innovations in this category mainly concern plant and machinery.

3.3 Circular Innovations[8]

This section concerns the circular innovations introduced by the surveyed firms and their distribution at the NUTS3 regional level. The questionnaire considers thirteen types of circular innovations: 1) "Reduction in water use in the production process", 2) "Reduction in the use of raw materials (including energy)", 3) "Change in product to minimise use of materials", 4) "Use of energy from renewable sources", 5) "Reduction in electricity generated from non-renewable sources", 6) "Increase in product durability", 7) 'Intervention to facilitate the disassembly of components', 8) 'Possibility of the product being repaired', 9) 'Change in product design to maximise recyclability', 10) 'Replacement of materials with high environmental impact with sustainable materials', 11) 'Reduction of waste emitted (per unit of output produced)', 12) 'Reuse of waste in own production cycle' and 13) 'Transfer of own waste to other companies, which, in turn, use it in their own production cycle'.

Figure 3.11 shows, for each province, the percentage of companies that have introduced circular innovations, without specifying a particular type. In Veneto, box (a), the highest percentages are found in the provinces of Belluno, Verona, and, above all, Vicenza. For Emilia-Romagna, box (b), the highest shares of circular innovators are found in the provinces of Bologna and Reggio Emilia, followed by Modena and Piacenza.

Figure 3.11 Share of firms that have introduced at least one circular innovation in 2020-2022 - a) Veneto and b) Emilia-Romagna



The first type of circular innovation considered, Table 3.8, concerns the reduction of water use throughout the production process. In both regions, approximately 8% of companies introduced innovations of this type in the three years 2020-2022 (of the total number of companies that introduced an innovation in general), but in Emilia-Romagna, a higher percentage of these same companies had already introduced innovations with the same purpose (76%) compared to Veneto

[8] In this section, the shares are based on the number of firms that have introduced at least one product, process, or organisational innovation, i.e., 480 for Veneto and 297 for Emilia-Romagna.

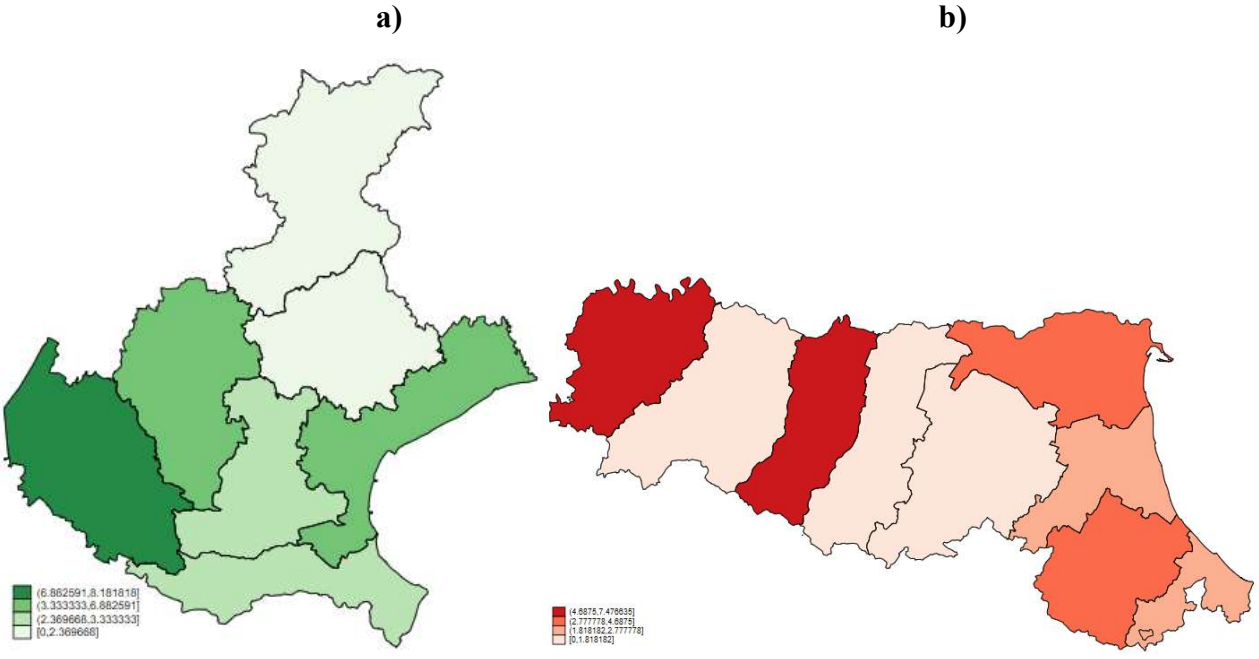
(56%). Another factor that differentiates the two regions is Veneto's tendency to introduce product innovations (83%) compared to Emilia-Romagna, where process innovations prevail (67%). Furthermore, in both regions, most of these innovations are new only to the company.

Table 3.8 Reduction in water usage in the production process

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	8.54%	7.07%
Before 2020[9]	56.10%	76.19%
Product	82.93%	33.33%
Process	19.51%	66.67%
Organisational	31.71%	38.10%
New to the company	95.12%	80.95%
New to the sector/market	4.88%	14.29%
Now to the world	0%	4.76%

As regards the distribution of companies innovating to reduce water use in Veneto, the highest percentages (Figure 3.12a) are found in the province of Verona, followed by Vicenza and Venice. Figure 3.12 (b), on the other hand, shows that in Emilia-Romagna, the provinces with the highest percentages are Piacenza and Reggio Emilia, followed by Ferrara and Forlì-Cesena.

Figure 3.12 Share of firms that introduced innovations to 'reduce water use in the production process' in 2020-2022 - a) Veneto and b) Emilia-Romagna



[9] Calculated on the 41 and 21 companies that answered "yes" to the previous question for Veneto and Emilia-Romagna, respectively.

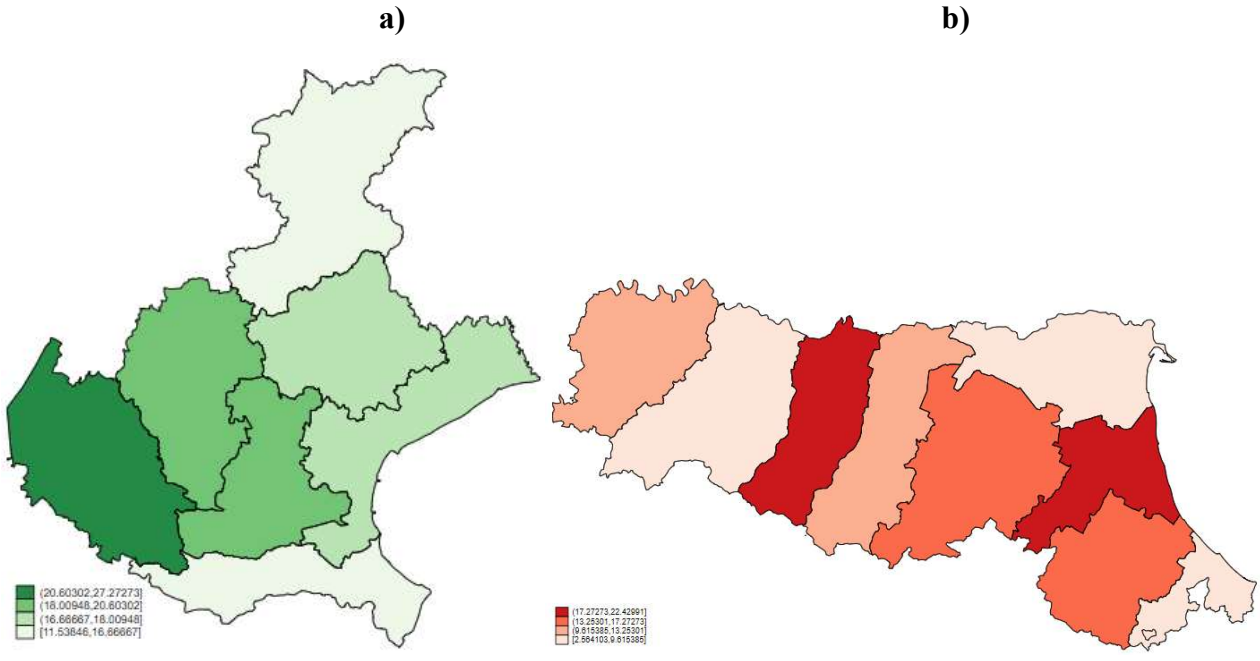
Table 3.9 refers to circular innovations aimed at reducing the use of raw materials (including energy). With regard to this type of innovation, there seems to be a slight prevalence of companies in Veneto compared to Emilia-Romagna. In both regions, innovations are mainly process-related, but in Emilia-Romagna, there are also higher percentages for product and organisational innovations. Again, most of the innovations are incremental, meaning they are new to the companies but not to the market or the world.

Table 3.9 Reduction in the use of raw materials (including energy)

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	37.5%	31.65%
Before 2020[10]	50.56%	45.74%
Product	28.33%	40.43%
Process	79.44%	74.47%
Organisational	33.89%	39.36%
New to the company	92.78%	90.43%
New to the sector/market	6.67%	9.57%
Now to the world	0.56%	0%

Box (a) in Figure 3.13 shows that the regions with the highest proportion of companies innovating to reduce their use of raw materials are Verona, followed by Vicenza and Padua. If we look at the same graph for Emilia-Romagna, box (b), the provinces with the highest shares are Reggio Emilia and Ravenna, followed by Bologna and Forlì-Cesena.

Figure 3.13 Share of firms that introduced innovations for "reducing the use of raw materials (including energy)" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[10] Calculated on the 180 and 94 companies that answered "yes" to the previous question for Veneto and Emilia–Romagna respectively.

With regard to companies that innovate with the aim of minimising the use of materials (Table 3.10), Veneto shows a higher percentage in the three years 2020-2022, while in Emilia-Romagna there is a higher percentage of companies that innovated in the three-year period 2020-2022 that were already innovating before 2020. In both regions, innovations are mainly product-related, although there is a significant share of process innovations in Emilia-Romagna. Furthermore, despite the incremental nature of these innovations, Emilia-Romagna shows higher percentages in both the "new to the sector" and "new to the world" innovation categories.

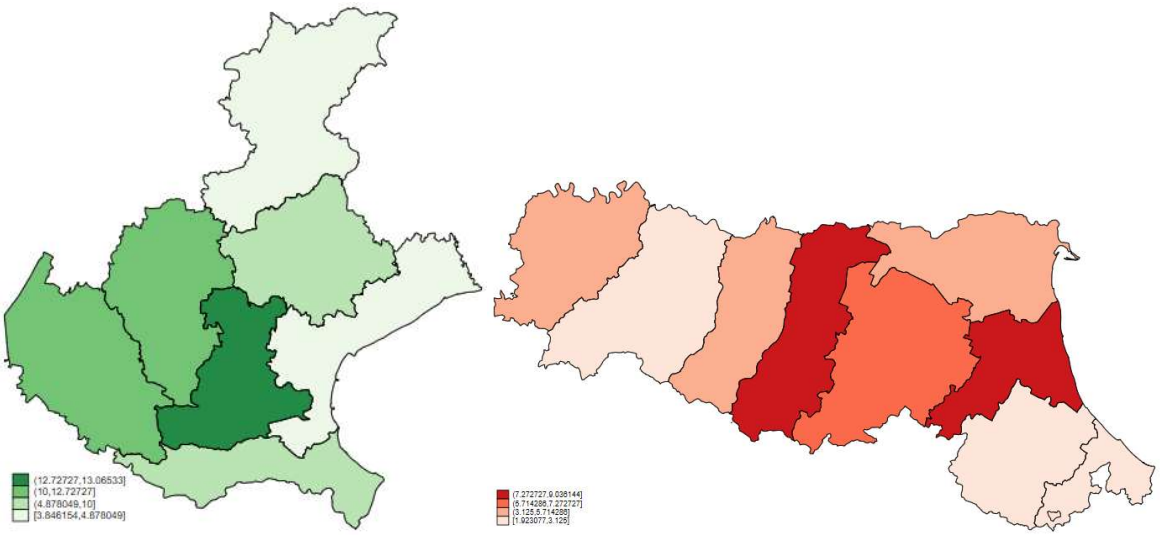
Table 3.10 Product change to minimise material usage

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	19.38%	13.13%
Before 2020[11]	54.84%	64.1%
Product	82.8%	76.92%
Process	43.01%	51.28%
Organisational	23.66%	25.64%
New to the company	82.8%	79.49%
New to the sector/market	16.13%	17.95%
Now to the world	1.08%	2.56%

The geographical distribution shows that in Veneto, Figure 3.14a, the highest percentages of businesses are found in Padua, followed by Verona and Vicenza. With regard to Emilia-Romagna, box (b), the highest percentages are found in Modena and Ravenna, followed by Bologna.

Figure 3.14 Share of firms that introduced innovations to "change the product to minimise the use of materials" in 2020-2022 – a) Veneto and b) Emilia-Romagna

a) **b)**



[11] Calculated on the 93 and 39 companies that answered 'yes' to the previous question for Veneto and Emilia-Romagna respectively.

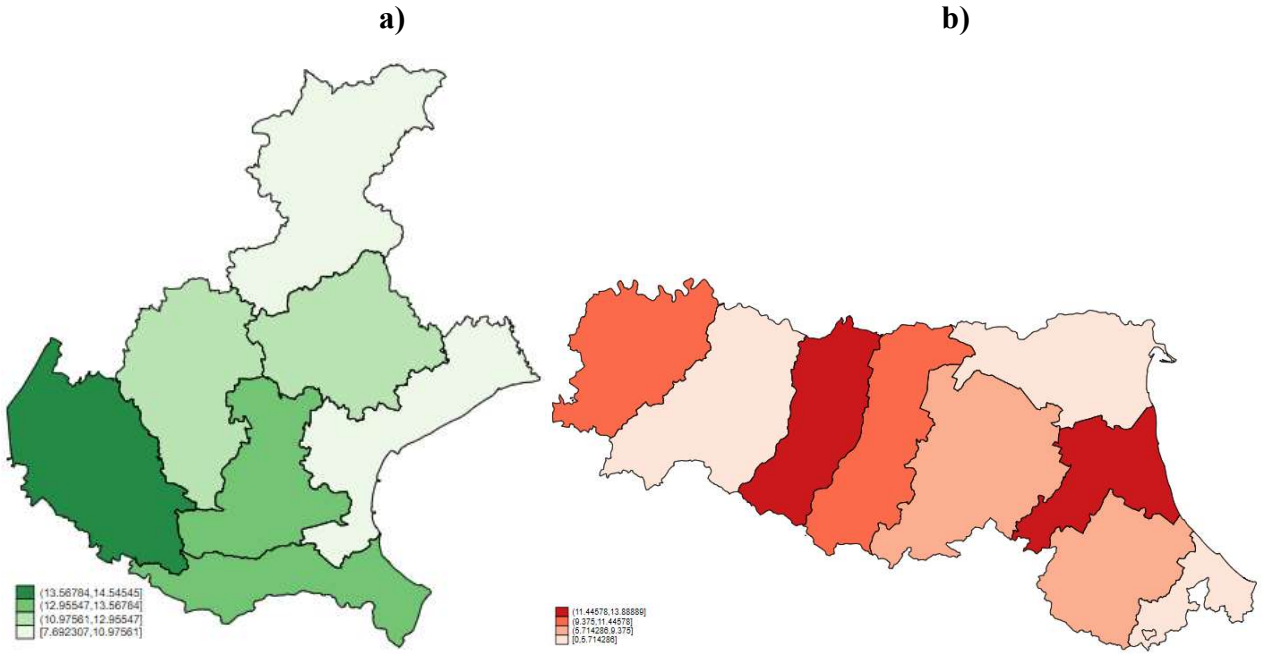
Let us now analyse the case of circular innovations related to the use of energy from renewable sources. Table 3.11 shows the percentage dynamics in the two regions. One of the main differences between the two regions is that in Emilia–Romagna there is a higher share of firms focusing on product innovation, 38% compared to 30% in Veneto. However, this difference does not change the order of preference; in both regions, the focus is on process innovation, followed by product innovation and finally organisational innovation. Furthermore, Veneto shows a higher percentage of innovations that are "new to the sector", but fewer innovations that are "new to the world".

Table 3.11 Energy use from renewable sources

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	18.75%	20.20%
Before 2020[12]	48.89%	45%
Product	30%	38.33%
Process	72.22%	70%
Organisational	20%	20%
New to the company	93.33%	95%
New to the sector/market	5.56%	1.67%
Now to the world	1.11%	3.33%

The geographical distribution in Veneto, Figure 3.15(a), shows high percentages of innovations aimed at greater use of renewable sources in Verona, Padua, and Rovigo, while for Emilia–Romagna, box (b), the provinces with the highest shares are Reggio Emilia and Ravenna.

Figure 3.15 Share of firms that introduced innovations related to the "use of energy from renewable sources" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[12] Calculated on the 90 and 60 companies that answered "yes" to the previous question for Veneto and Emilia-Romagna, respectively.

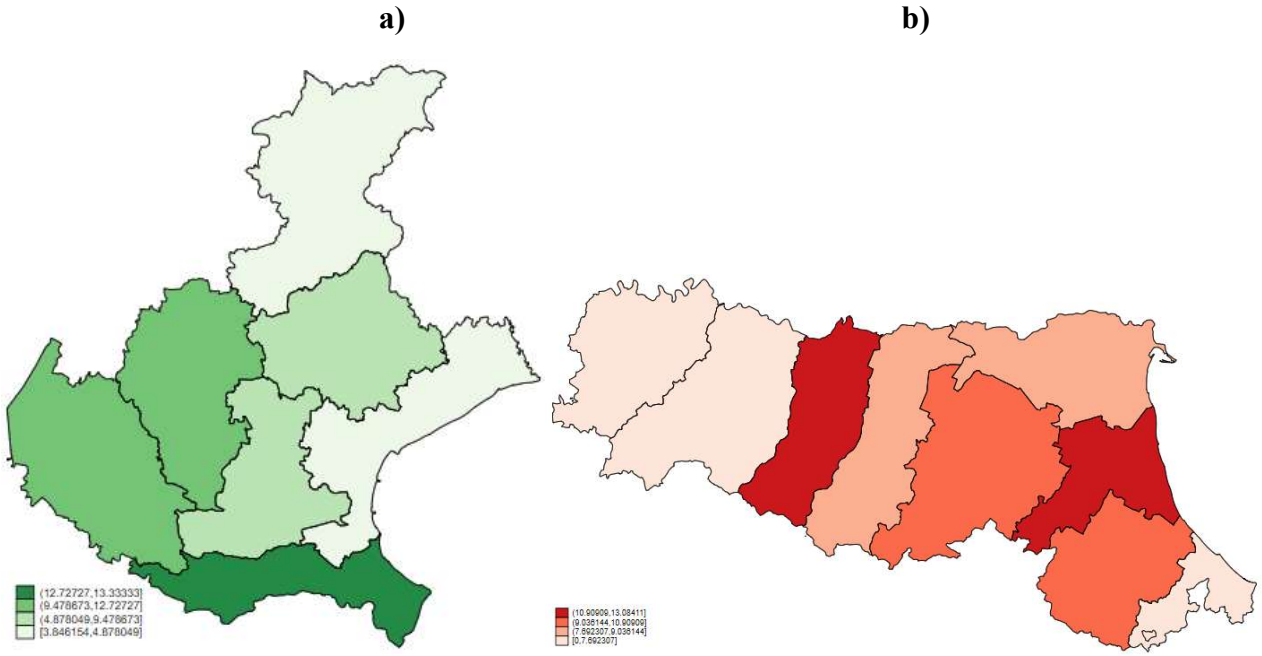
Looking at Table 3.12, the shares of firms that have introduced innovations to reduce electricity generated from non-renewable sources are similar across regions, both in 2020-2022 and before 2020. The prevailing form of this type of circular innovation is process-based, with Veneto showing a slightly higher percentage of organisational innovations than Emilia-Romagna. Once again, the nature of this innovation is predominantly incremental.

Table 3.12 Reduction of electricity generated from non-renewable sources

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	23.96%	19.53%
Before 2020 [13]	45.22%	41.38%
Product	26.09%	31.03%
Process	66.09%	72.41%
Organisational	28.7%	22.41%
New to the company	95.65%	94.83%
New to the sector/market	1.74%	5.17%
Now to the world	2.61%	0%

Figure 3.16 shows the percentages of enterprises that have introduced innovations to reduce electricity generated from non-renewable sources. The map of Veneto indicates Rovigo as the province with the highest share, followed by Verona and Vicenza. For Emilia–Romagna, the highest percentages are found in Reggio Emilia and Ravenna, followed by Bologna and Forlì–Cesena.

Figure 3.17 Share of firms that introduced innovations for "reducing electricity generated from non-renewable sources" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[13] Calculated on the 115 and 58 companies that answered "yes" to the previous question for Veneto and Emilia–Romagna respectively.

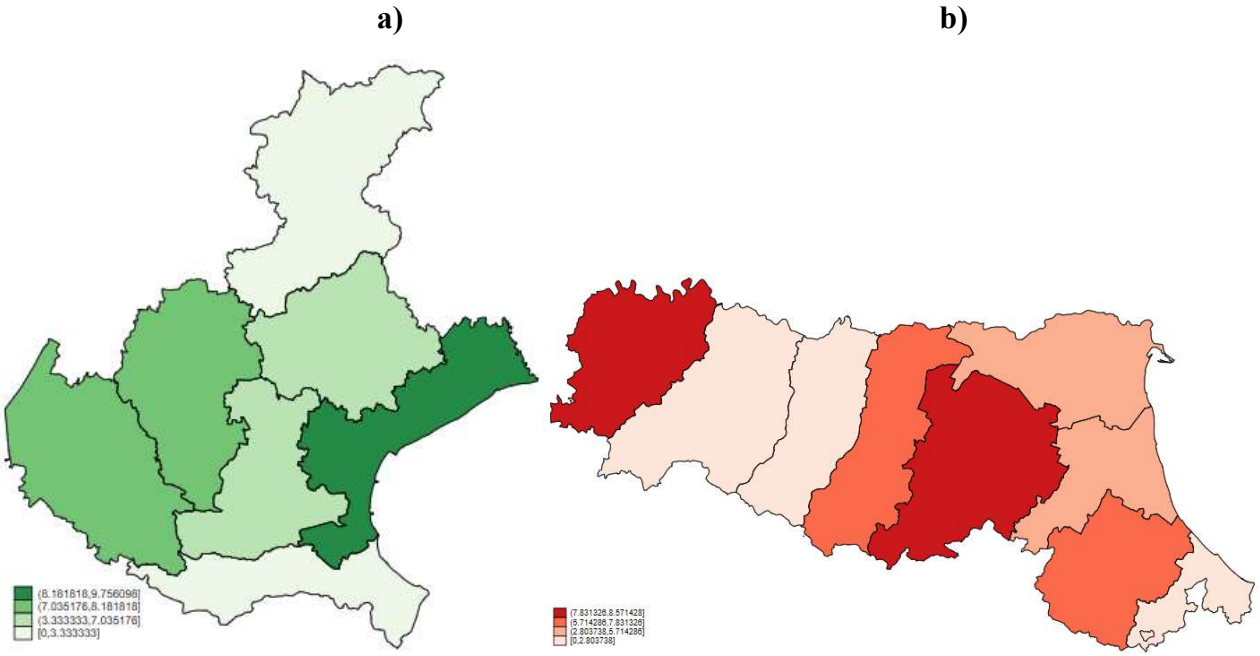
Concerning the increasing product durability, Table 3.13 shows that in both regions, approximately 13% of companies have introduced innovations for this purpose. The main difference between the two regions concerns the percentage of "world-first" innovations, which is already high in Veneto at 3.28%, but reaches almost 8% in Emilia-Romagna. Of all types of circular innovations, this is the one in which the two Italian regions seem to be most innovative at an international level.

Table 3.13 Increase in product durability

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	12.71%	12.79%
Before 2020[14]	63.93%	55.26%
New to the company	80.33%	73.68%
New to the sector/market	16.39%	18.42%
Now to the world	3.28%	7.89%

In Veneto, as shown in Figure 3.17, the provinces with the highest proportion of enterprises that have introduced innovations to increase product durability are Venice, Verona, and Vicenza. In Emilia–Romagna, the highest percentages are in Piacenza and Bologna, followed by Modena and Forlì–Cesena.

Figure 3.17 Share of firms that introduced innovations for "Increased product durability" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[14] Calculated on the 61 and 38 companies that answered 'yes' to the previous question for Veneto and Emilia–Romagna respectively.

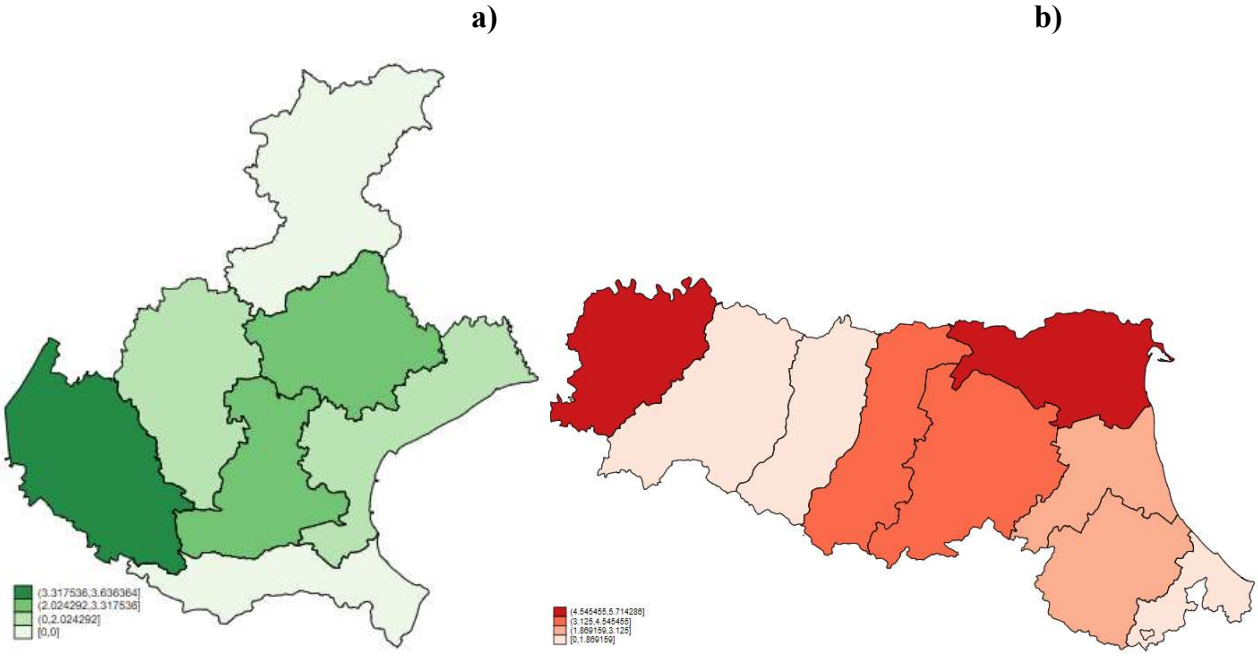
As shown in Table 3.14, in both Veneto and Emilia-Romagna, the percentage of companies innovating to promote the disassembly of components in 2020-2022 is particularly low when compared to other types of circular innovations. On the other hand, the number of companies that innovated in the 2020-2022 period and had already innovated before 2020 is particularly high in Emilia-Romagna (71%), almost double the percentage for Veneto (41%). It can also be noted that Emilia-Romagna has a very high percentage of innovations that are "new to the sector", reaching almost 15%, compared to Veneto, where this percentage is less than 5%.

Tabella 3.14 Intervention aimed at facilitating the disassembly of components

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	4.58%	7.07%
Before 2020 [15]	40.91%	71.43%
New to the company	95.45%	85.71%
New to the sector/market	4.55%	14.29%
Now to the world	0%	0%

The geographical distribution shows (Figure 3.18) that, in Veneto, this type of innovation is relatively prevalent in the province of Verona, but also in the provinces of Padua and Treviso. In Emilia-Romagna, the highest percentages are recorded in the provinces of Piacenza and Ferrara, followed by Modena and Bologna.

Figure 3.18 Share of firms that introduced innovations to "facilitate the disassembly of components" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[15] Calculated on the 22 and 21 companies that answered 'yes' to the previous question for Veneto and Emilia-Romagna, respectively.

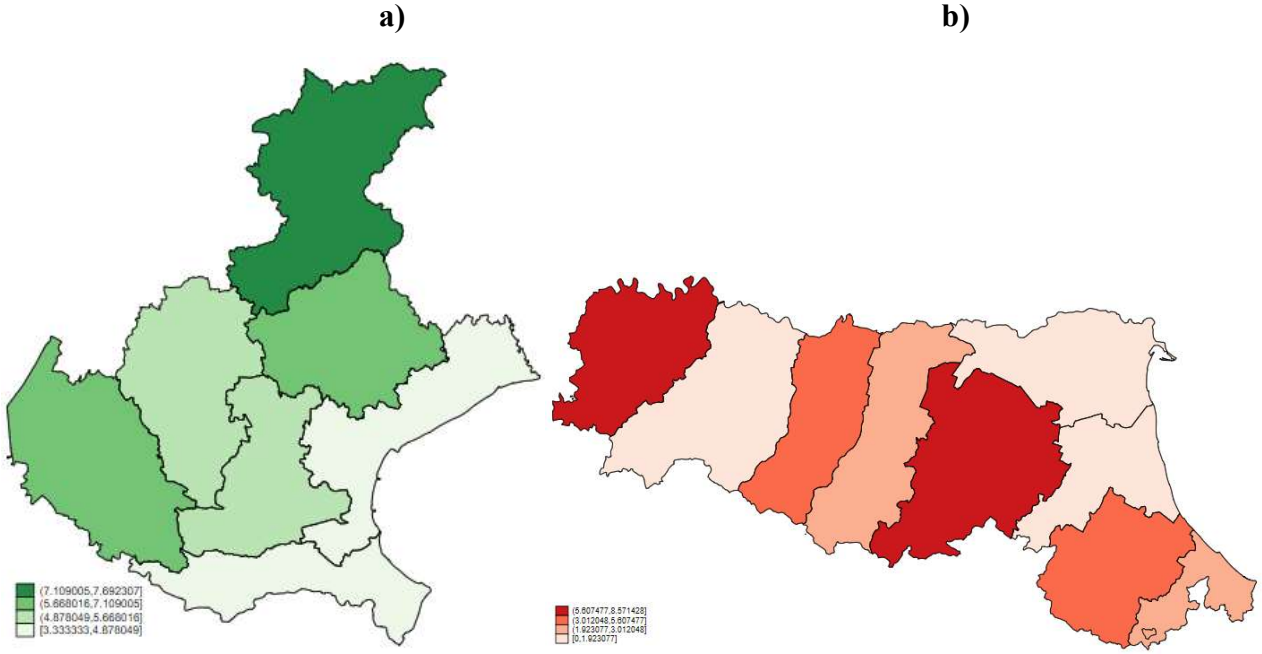
Table 3.15 shows that in both regions approximately 10% of enterprises introduced innovations between 2020 and 2022 aimed at increasing the repairability of their products. However, Emilia-Romagna differs from Veneto in that a large share of these firms had already introduced such innovations before 2020 (71%), whereas in Veneto this figure is only 28%. In Veneto, a very high proportion of innovations are classified as "new to the sector" (26%), while in Emilia-Romagna this share is considerably lower (7%). By contrast, Emilia-Romagna reports a share of innovations that are "new to the world" equal to 3.57%, compared with 0% in Veneto.

Table 3.15 Possibility of the product being repaired

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	11.04%	9.43%
Before 2020 [16]	28.3%	71.43%
New to the company	73.58%	89.29%
New to the sector/market	26.42%	7.14%
Now to the world	0%	3.57%

Moving on to the provincial distribution in Veneto, Figure 3.19 box (a), the provinces with the highest percentages of companies that have introduced this type of circular innovation are Belluno, Treviso, and Verona, while in Emilia–Romagna they are mainly Bologna and Piacenza, followed by Reggio Emilia and Forlì–Cesena.

Figure 3.19 Share of firms that introduced innovations for "product repairability" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[16] Calculated based on the 53 and 28 companies that answered 'yes' to the previous question for Veneto and Emilia–Romagna, respectively.

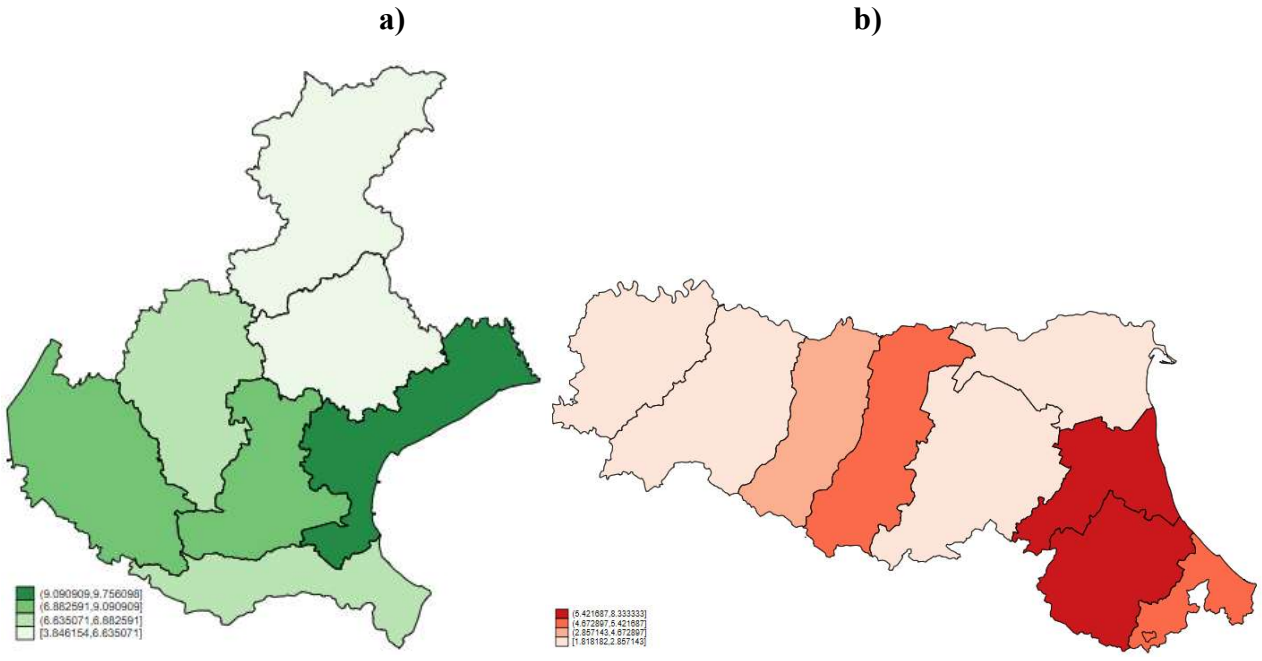
Table 3.16 shows a similar picture in the two regions with regard to innovations aimed at changing product design to maximise recyclability. 14% of innovative enterprises in Veneto and around 10 % in Emilia-Romagna have innovated with this aim in mind in the three-year period 2020-2022, while more than half of them stated that they had already introduced similar innovations previously. Finally, it is interesting to note that, despite the predominantly incremental nature of these innovations, in both regions, innovations introduced that are "new to the sector" account for between 22% and 25%.

Table 3.16 Change in product design to maximise recyclability

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	13.75%	9.43%
Before 2020 [17]	54.55%	57.14%
New to the company	77.27%	75%
New to the sector/market	22.73%	25%
Now to the world	0%	0%

In Figure 3.20, panel a, we can see that in Veneto, the highest concentration of innovative companies is in the provinces of Venice, Verona, and Padua. In Emilia–Romagna, on the other hand, the highest percentages are in Ravenna and Forlì–Cesena in Romagna, followed at some distance by Modena and Rimini.

Figure 3. Share of firms that introduced innovations for "changing product design to maximise recyclability" in 2020-2022 – a) Veneto and b) Emilia-Romagna



With regard to *the transition from materials with a high environmental impact to sustainable materials*, Table 3.17 reveals that Veneto has a higher percentage of companies that have innovated

[17] Calculated on the 66 and 28 companies that answered 'yes' to the previous question for Veneto and Emilia-Romagna respectively.

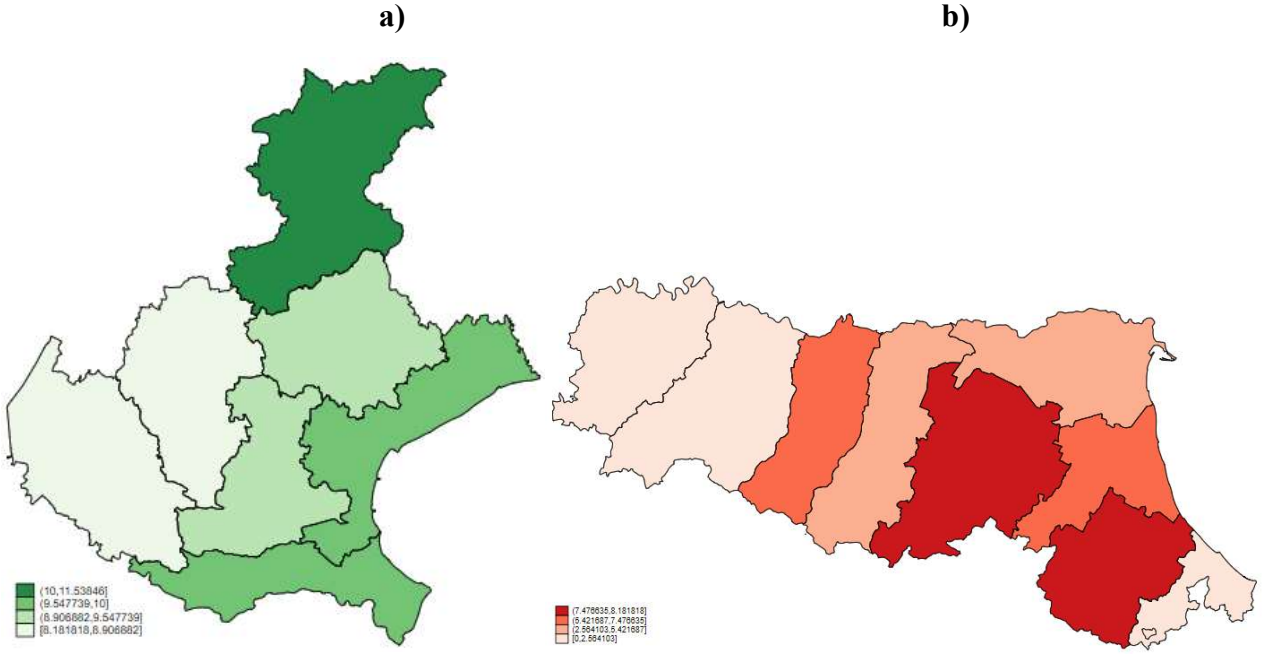
(17%) than Emilia-Romagna (12%). Looking at companies that had already innovated before 2020, we find percentages above 50% in both regions. However, there is a difference when looking at the 25% of companies in Emilia-Romagna that have introduced innovations that are "new to the sector", a high figure when compared to that of Veneto (16%), where the share of innovations that are new only to the firm itself (83%) clearly prevails.

Table 3.17 Replacement of materials with high environmental impact with sustainable materials

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	17.08%	12.12%
Before 2020 [18]	60.98%	52.78%
New to the company	82.93%	75%
New to the sector/market	15.85%	25%
Now to the world	1.22%	0%

Figure 3.21 shows the geographical distribution of innovative companies in terms of the use of more sustainable materials. In Veneto, we find high percentages for the provinces of Belluno, followed by Venice and Rovigo, while in Emilia–Romagna, the provinces with the highest percentages are Bologna and Forlì–Cesena, followed by Reggio Emilia and Ravenna.

Figure 3.21 Share of firms that introduced innovations to "replace materials with a high environmental impact with sustainable materials" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[18] Calculated on the 82 and 36 companies that answered 'yes' to the previous question for Veneto and Emilia-Romagna respectively.

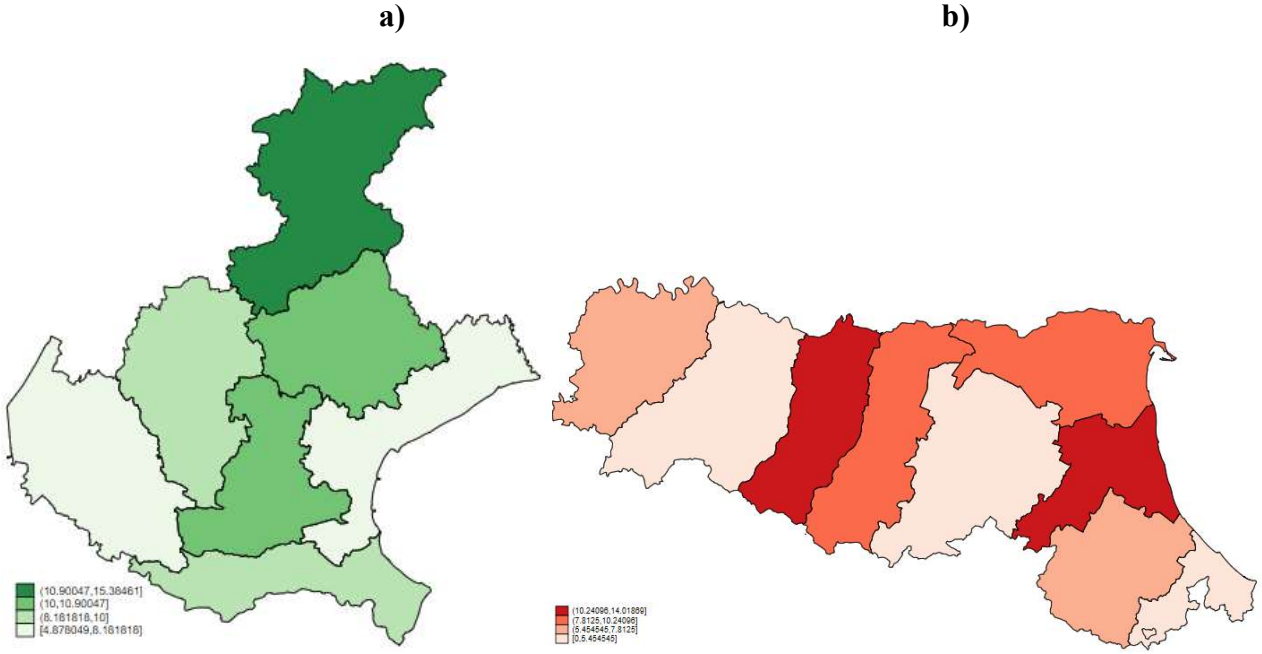
Table 3.18 presents the main characteristics of innovations in the field of waste reduction. In both regions, innovations were introduced by approximately 18% of innovative enterprises in the three-year period 2020-2022, and of these enterprises, well over half had already introduced the same type of innovations previously. In both regions, the prevailing type of innovation is process-based and incremental in nature, although it is worth noting that in Emilia-Romagna, there are higher percentages of both "new to the sector" (9%) and "new to the world" (4%) innovations.

Table 3.18 Reduction in waste generated (per unit of output produced)

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	18.13%	17.85%
Before 2020 [19]	57.47%	66.04%
Product	40.23%	49.06%
Process	65.52%	64.15%
Organisational	36.78%	35.85%
New to the company	93.1%	86.79%
New to the sector/market	6.9%	9.43%
Now to the world	0%	3.77%

The distribution in Veneto, as shown in Figure 3.22 box (a), shows high shares of innovations for waste reduction, especially in Belluno, but also in Padua and Treviso. In box (b), for Emilia–Romagna, Reggio Emilia and Ravenna stand out, followed by Modena and Ferrara.

Figure 3.22 Share of firms that introduced innovations to "reduce waste emitted (per unit of output produced)" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[19] Calculated on the 87 and 53 companies that answered 'yes' to the previous question for Veneto and Emilia-Romagna respectively.

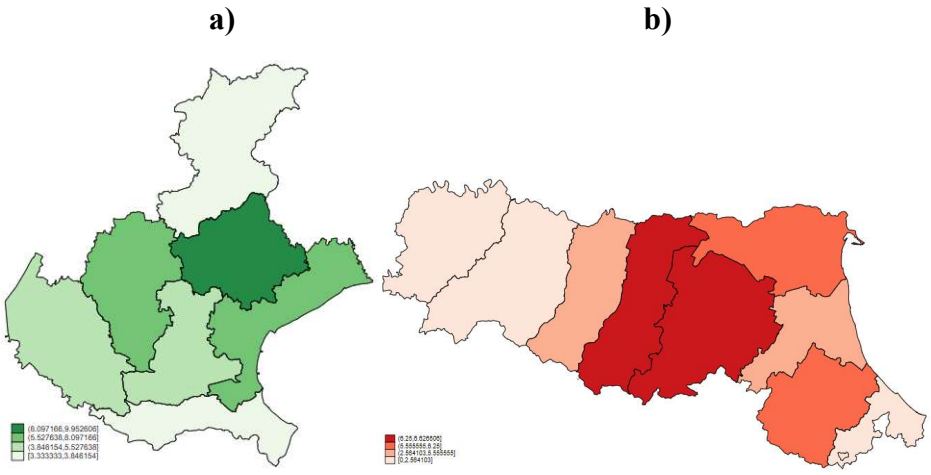
Still about waste, Table 3.19 shows that 14% of companies in Veneto and 11% of companies in Emilia-Romagna have innovated in the field of waste reuse in their production cycle in the three-year period 2020-2022. A high percentage of these companies, around 72% in both regions, had already introduced innovations for this purpose. The two regions differ in that in Veneto, product and process innovations have very similar percentages, while in Emilia-Romagna there is a much more pronounced trend towards process innovations than product innovations. In both regions, however, the introduction of organisational innovations is lower. Neither region has introduced innovations that are "new to the world", but Emilia-Romagna shows a percentage that is approximately double that of innovations that are "new to the sector".

Table 3.19 Reuse of waste in own production cycle

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	13.54%	10.77%
Before 2020 [20]	72.31%	71.88%
Product	55.38%	46.88%
Process	56.92%	68.75%
Organisational	29.23%	37.5%
New to the company	92.31%	84.38%
New to the sector/market	7.69%	15.63%
Now to the world	0%	0%

The distribution across the various provinces is shown in Figure 3.23. The map of Veneto, panel (a), shows high percentages of companies that have introduced innovations for the reuse of waste in their production cycle, especially in the province of Treviso, followed by Vicenza and Venice. In the case of Emilia-Romagna, box (b), the provinces of Modena and Bologna are particularly dense with innovative companies, followed by Ferrara and Forlì-Cesena.

Figure 3.23 Share of firms that introduced innovations for "reusing waste in their production cycle" in 2020-2022 – a) Veneto and b) Emilia-Romagna



[20] Calculated on the 65 and 32 companies that answered 'yes' to the previous question for Veneto and Emilia-Romagna respectively.

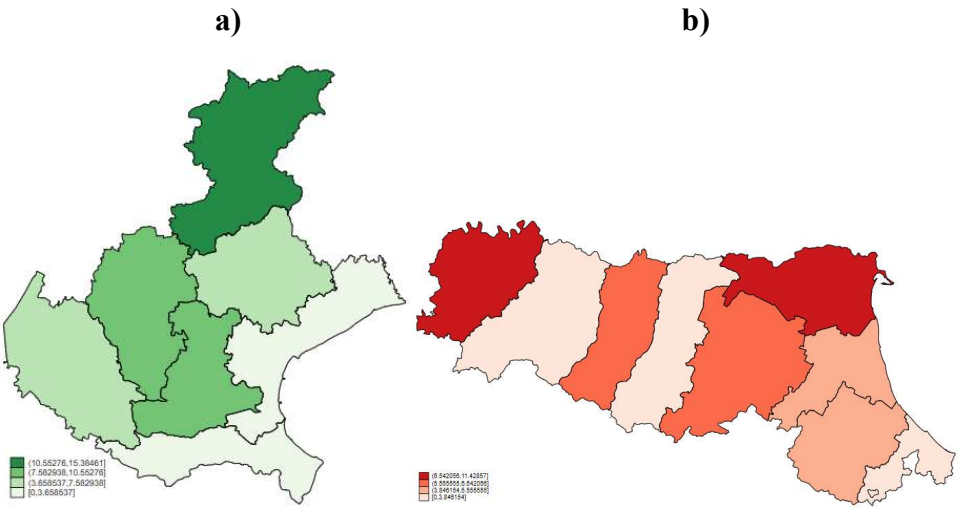
The last type of circular innovation considered concerns the transfer of waste to other companies, again for reuse. Table 3.20 shows a higher percentage of companies in Veneto (16%) that have introduced innovations for this purpose in 2020-2022 compared to Emilia-Romagna (11%). A significant difference between the two regions emerges when looking at the types of innovation preferred in each region. In Emilia-Romagna, there is an even distribution between product, process, and organisational innovations, while in Veneto, there is clearly a high percentage of process innovations. In terms of the degree of originality of the innovations, the two regions do not show any significant differences.

Table 3.20 Transfer of own waste to other companies

	VENETO	EMILIA-ROMAGNA
Innovations introduced in the three years	15.63%	11.11%
Before 2020 [21]	69.33%	75.76%
Product	37.33%	33.33%
Process	61.33%	36.36%
Organisational	41.33%	42.42%
New to the company	92%	90.91%
New to the sector/market	8%	9.09%
Now to the world	0%	0%

Looking at Figure 3.24, we can see which provinces are most significant in percentage terms for Veneto and Emilia–Romagna. For Veneto, these provinces are Belluno, first and foremost, followed by Vicenza and Padua, while for Emilia–Romagna they are Piacenza and Ferrara, followed by Reggio Emilia and Bologna.

Figure 3.24 Share of firms that introduced innovations for "transferring their waste to other enterprises that use it in their production cycle" in 2020-2022 – a) Veneto and b) Emilia-Romagna

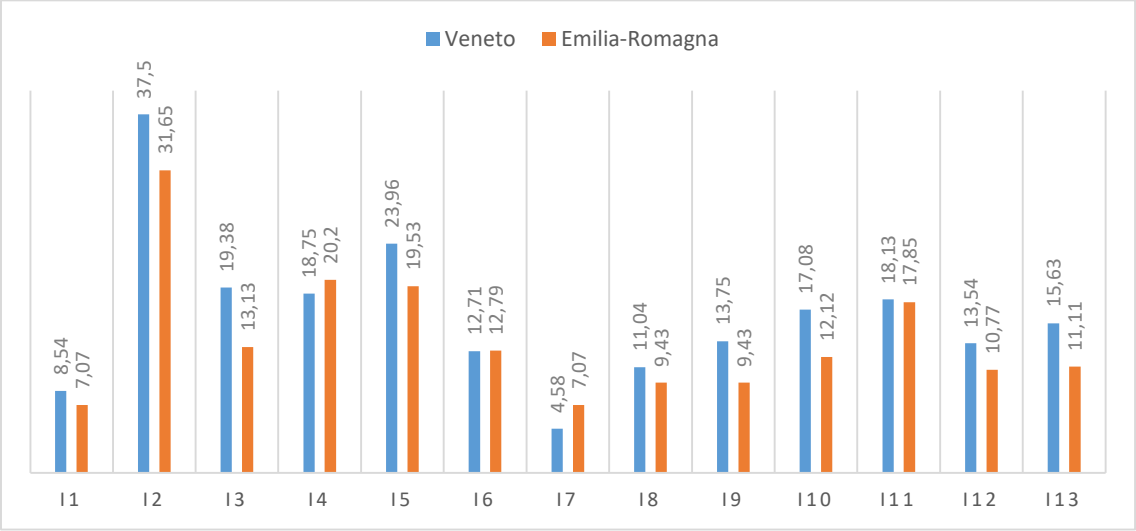


[21] Calculated on the 75 and 33 companies that answered 'yes' to the previous question for Veneto and Emilia-Romagna respectively.

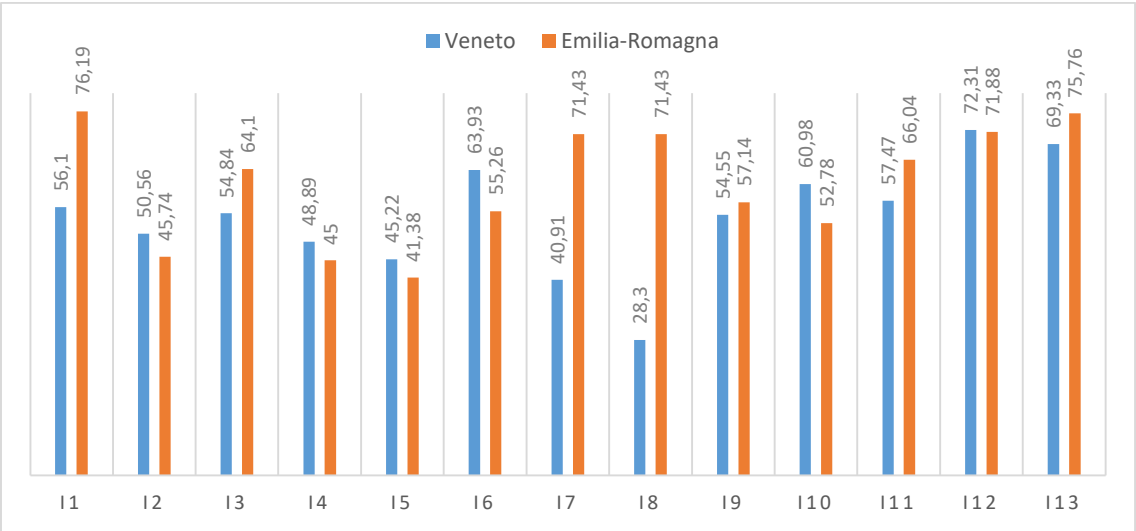
After presenting a detailed overview considering all individual types of circular innovations, Chart 3.11 provides an overview comparing the percentages of companies that innovated in 2020-2022, box (a), and among these, those that had already innovated previously, box (b), for all types of innovations.

Graph 3.11 Circular innovations introduced in 2020-2022 (a) and innovations introduced before 2020[22]

a)



b)



From box (a), we can see that the most widespread type of circular innovation is that linked to the reduction of raw materials used in production processes (I2), a strategy that is understandable in light of the recent shocks linked to both the pandemic and the war in Ukraine. Next, with slight differences

[22] In the Appendix, Table A5, lists the categories indicated in the table as I1, I2,…

between the two regions, are innovations aimed at either saving electricity (I4) or using electricity from renewable sources (I5). The least popular categories, on the other hand, are innovations aimed at reducing water use (I1), product disassembly (I7), or product repairability (I8). However, it should be noted from box (b) that, for almost all types of circular innovation, the companies surveyed stated that they already had experience, having introduced them in the years before 2020.

One final aspect we will now consider concerns the means of financing innovative activity by businesses in 2020-2022. Table 3.21 clearly shows that, in both regions, the dominant channels are internal resources and conventional bank loans. The use of subsidies or public funds accounts for around 8% of the sample, while the percentages for other types of financing are negligible.

Table 3.21 Financing instruments

	Veneto	Emilia-Romagna
Internal Resources	86.46%	80.13%
Bank loan (standard))	26.46%	30.98%
Dedicated bank loan (e.g. green bonds)	1.67%	2.02%
New share issues	0.21%	0.67%
Public funds or subsidies (local, national or international))	8.33%	7.74%
Dedicated alternative financing methods (e.g. crowdfunding)	0.63%	1.01%

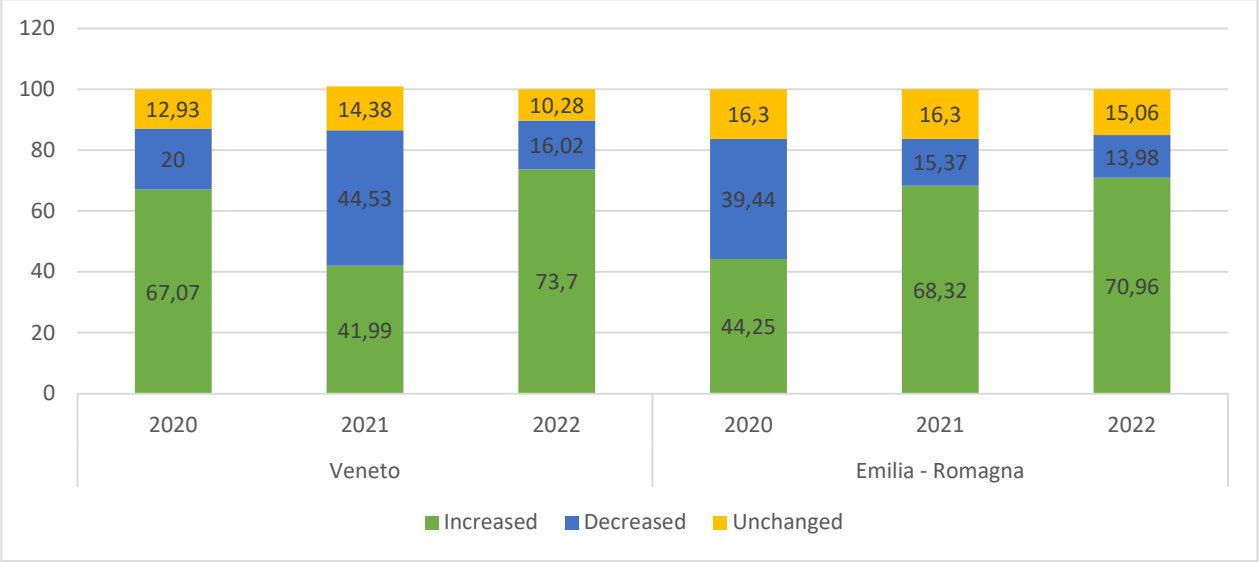
3.4 The effects of COVID-19

A specific section of the questionnaire is dedicated to understanding the impact that COVID-19 has had on firms in terms of turnover and investments in circular innovation practices.

Respondents were asked to compare their economic performance during the pandemic years (2020, 2021, and 2022) with that of 2019. As shown in Figure 3.12, the turnover dynamics differed across the two regions in 2020 and 2021. In Veneto, more than two-thirds of firms reported an increase in turnover in 2020, while only 20% experienced a decline compared to 2019. In 2021, however, the share of firms reporting higher turnover fell to around 40%, whereas the proportion of firms experiencing a decline relative to 2019 rose to nearly 45%.

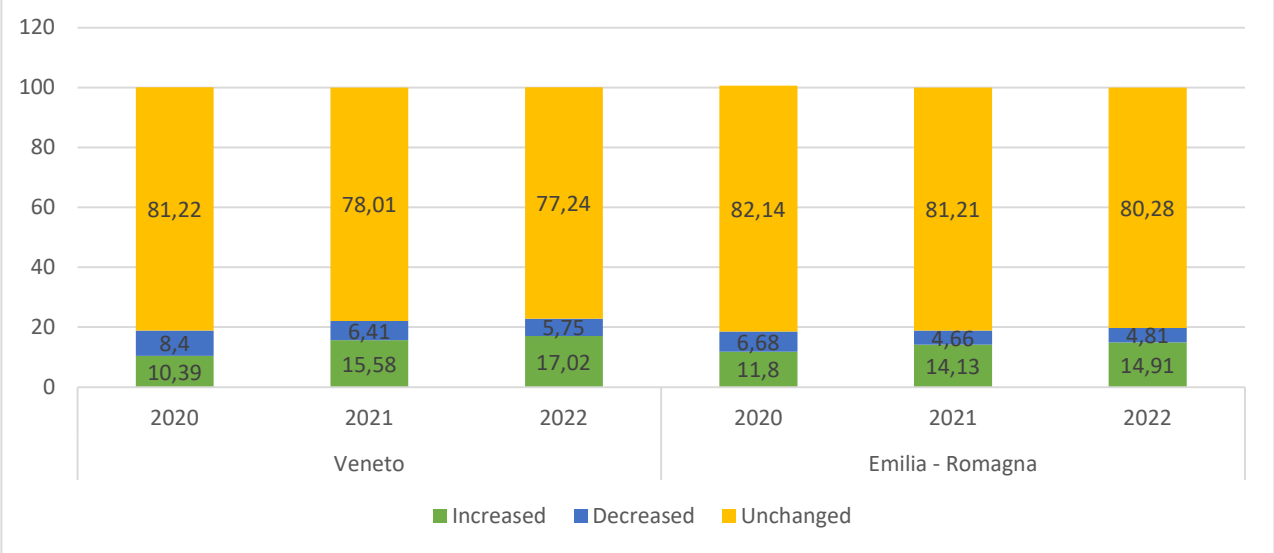
In Emilia-Romagna, the pattern appears to be the opposite. The year 2020 was the most challenging for firms, with almost 40% reporting a decrease in turnover and around 45% reporting an increase relative to 2019. By contrast, 2021 marked a recovery, with approximately 68% of firms recording higher turnover than in 2019 and only 15% reporting a decline. Overall, this suggests that the negative effects of the pandemic materialized earlier in Emilia-Romagna, whereas in Veneto, after an initially more resilient response, the economic difficulties associated with COVID-19 became more pronounced in 2021. In both regions, 2022 emerges as the most favourable year in terms of turnover performance, with around 70% of firms reporting an increase, 15% no change, and 15% a decrease compared to 2019.

Graph 3.12 Comparison of turnover with 2019 for the years 2020, 2021, and 2022



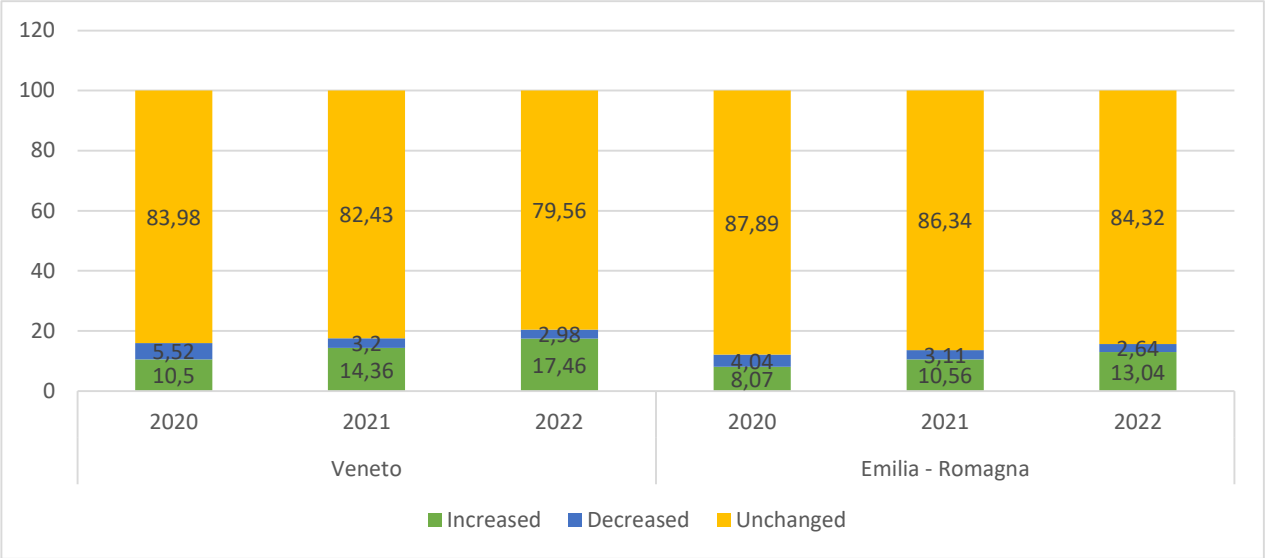
Concerning investment in non-circular innovations, Graph 3.13 shows that in Veneto, there will be a slight increase over the three years 2020-2022 in the share of firms that have increased their investments compared to 2019, coupled with a decrease in the proportion of companies that have maintained or reduced their volume of investment in non-circular innovations. In general, for most of them, the volume of investment remained unchanged (81.22% in 2020, 78.01% in 2021, and 77.24% in 2022). In Emilia-Romagna, too, there was an increase in the share of firms that made more investments than in 2019 over the three years, although the growth was lower than in Veneto, rising from 11.8% in 2020 to 14.91% in 2022. A further similarity between the two regions can be seen in the high share of firms that kept their investment volume unchanged, 82.14% in 2020, 81.21% in 2021, and 80.28% in 2022.

Graph 3.13 Investment in non-circular innovations compared to 2019



The dynamics of investment in circular innovations in 2020-2022 for the two regions, Graph 3.14, is very similar to those described for circular innovations. In both regions, there has been an increase over the years in the share of firms that have increased their investments compared to 2019, which goes hand in hand with a decrease in the share of those that have decreased or maintained their investments at the same level as in 2019. While the dynamics are similar, the different types of investment differ in that, in each year and for both regions, the share of firms that have increased their investment in non-circular innovations is almost always higher than the corresponding share for circular innovations. The only exceptions are 2020 and 2022 in Veneto, where the share of investment in circular innovations slightly predominates.

Graph 3.14 Investments in circular innovations compared to 2019



To conclude this section of the questionnaire concerning the pandemic, respondents are asked to give their opinion on the importance of certain factors in dealing with crises. For each factor, it is possible to assign a rating from 1 – not at all important to 4 – very important. Looking at Graph 3.15, which shows the average importance of each factor in dealing with the crisis, it is immediately apparent that in both regions, firms give similar importance to the various factors, although the average importance assigned in Emilia-Romagna tends to be slightly lower than that assigned in Veneto. In general, it seems that the factors considered most important, with an average above 3 in both regions, are "Quality of the product/service offered" and "Reduction of production costs". These are followed by "Quality of the production process" and "Training for employees". Factors such as "Reduction of investment in research and development" and "Reduction of investment in innovations to reduce environmental impact" stand out for having obtained a particularly low average, around 2.1.

Graph 3.15 Importance (average) of various factors in dealing with crises

4. The determinants of circular innovation: an econometric analysis

Descriptive framework

After reviewing the various sections of the survey and presenting a descriptive overview of the innovative activities (circular and non-circular) of the companies interviewed, we will now present an econometric analysis of the factors that explain their relative introduction. These factors are divided into three categories: structural characteristics of the company, adoption of 4.0 technologies, and sources of financing for innovative activities. The dependent variables that will be used, on the other hand, will concern the introduction of product, process, or organisational innovations, the development and number of patents, and specifically green patents aimed at mitigating the environmental impact of production processes, and finally, the introduction of circular innovations, specifically oriented towards the 3R principles (reduction, recycling, and reuse).

Tables 4.1 and 4.2 present the main descriptive statistics for the innovative output variables used in the analysis. In Table 4.1, in line with what was described in Section 3 above, we note that the introduction of new products, processes, or organisational methods concerns about one third of the sample observed, with a higher average value in Veneto than in Emilia-Romagna. As regards the degree of novelty of the products, Table 4.1 shows that the most frequent type is incremental, i.e., new only for the company, while radical product innovations, i.e., new to the world, are much rarer. In line with past trends among Italian and European firms (see, for example, the various reports of the European Innovation Scoreboard published by the European Commission), the share of turnover deriving from the sale of innovative products stands at around 10%, slightly higher in Emilia-Romagna. The propensity to patent is also low (around 7% on average), while for those who do patent, the average number of patents (or patent applications) is between 2 and 3.

Table 4.1. Overall innovation: descriptive statistics

Innovation	Average	Std. Dev.	Min	Max	Average ER	Average Veneto
INNOPROD	0.351	0.478	0	1	0.311	0.380
INNOPROC	0.360	0.480	0	1	0.334	0.379
INNOORG	0.318	0.466	0	1	0.298	0.333
INNO_COMPANY	0.213	0.410	0	1	0.186	0.232
INNO_MARKET	0.123	0.329	0	1	0.110	0.133
INNO_WORLD	0.015	0.121	0	1	0.014	0.015
FATT_INNO$_{2020\text{-}22}$	0.097	0.120	0.01	1	0.106	0.091
FATT_INNO$_{2020}$	0.069	0.109	0	1	0.075	0.065
FATT_INNO$_{2021}$	0.001	0.001	0.001	0.01	0.001	0.001
FATT_INNO$_{2022}$	0.128	0.160	0.01	1	0.139	0.121
PATENTS	0.074	0.262	0	1	0.067	0.080
NUMBER of PATENTS	2.652	3.564	0	25	2.302	2.861

Table 4.2, on the other hand, shows that, with an average once again around 30%, the highest frequency of circular innovation companies is in Veneto. Of the three methods, the one linked to the reduction of raw materials and energy clearly prevails over the other two. Looking at the thirteen individual innovative activities in detail, we note that the most frequent are I2 (linked to the reduction of raw materials) and I4 (use of energy from renewable sources).

Table 4.2. Circular Innovation: descriptive statistics

Circular Innovation	Average	Std. Dev.	Min	Max	Average ER	Average Veneto
INNOCIRC	0.323	0.468	0	1	0.269	0.361
INNO_REDUCE	0.261	0.439	0	1	0.210	0.297
INNO_REUSE	0.168	0.374	0	1	0.140	0.188
INNO_RECYCLE	0.155	0.362	0	1	0.134	0.170
INNO I1	0.040	0.196	0	1	0.033	0.045
INNO I2	0.177	0.382	0	1	0.146	0.199
INNO I3	0.086	0.280	0	1	0.061	0.104
INNO I4	0.113	0.217	0	1	0.093	0.127
INNO I5	0.096	0.295	0	1	0.090	0.101
INNO I6	0.064	0.245	0	1	0.059	0.067
INNO I7	0.028	0.164	0	1	0.033	0.024
INNO I8	0.053	0.224	0	1	0.043	0.060
INNO I9	0.061	0.239	0	1	0.043	0.073
INNO I10	0.077	0.266	0	1	0.056	0.092
INNO I11	0.090	0.287	0	1	0.082	0.096
INNO I12	0.063	0.242	0	1	0.050	0.072
INNO I13	0.070	0.255	0	1	0.051	0.083

Tables 4.3, 4.4, and 4.5 show descriptive statistics of the factors that may have stimulated the company's innovative activity over the three years. Table 4.3 focuses on general characteristics such as size, age, ownership and/or organisational structure, type of management, and main markets. It is

interesting to note that Veneto companies are on average larger in terms of number of employees, more mature, slightly more family-owned, with a higher proportion of women and young people among managers, and more exposed to international markets. Emilia-Romagna companies, on the other hand, are on average more oriented towards local or regional markets and more likely to employ graduates among their managers. The differences in other characteristics appear negligible.

Table 4.3. Structural characteristics of enterprises: descriptive statistics

Characteristics	Average	Std. Dev.	Min	Max	ER Average	Veneto Average
$EMPLOYEES_{2020}$	38.38	226.2	0	8130	33.98	41.51
AGE	30.82	19.57	0	168	29.33	31.88
GROUP	0.145	0.352	0	1	0.150	0.141
SUPPLY-CHAIN	0.144	0.351	0	1	0.148	0.141
DISTRICT	0.076	0.264	0	1	0.070	0.080
NETWORK	0.054	0.227	0	1	0.056	0.053
CERTIFICATION	0.469	0.499	0	1	0.455	0.478
FAMILY-RUN COMPANY	0.460	0.499	0	1	0.427	0.484
WOMEN MANAGER	0.385	0.487	0	1	0.362	0.402
YOUNG MANAGER	0.158	0.365	0	1	0.151	0.164
GRADUATED MANAGER	0.294	0.456	0	1	0.309	0.283
LOCAL MARKET	0.280	0.354	0	1	0.327	0.246
REGIONAL MARKET	0.239	0.286	0	1	0.249	0.232
NATIONAL MARKET	0.289	0.291	0	1	0.267	0.305
FOREIGN MARKET	0.192	0.277	0	1	0.157	0.218

Table 4.4 shows descriptive statistics on the technological inputs used by firms, including R&D activity. With regard to enabling technologies, compared to an average of 41% of firms using them, we note that the ones in Veneto show a greater propensity to use them in 2020-22. However, as shown in Graph 3.10, firms in Emilia-Romagna show a greater propensity to introduce several of these technologies before 2020. Furthermore, in Emilia-Romagna, the average number of technologies used is slightly higher. Among the 4.0 technologies, the most widely adopted are, on average, robotics and technologies falling within the "other" category, while the least used are augmented/virtual reality and artificial intelligence. Finally, we note that only 23% of the sample is involved in R&D activities, with an average share of turnover dedicated to this well below 1%.

Table 4.4. Adoption of enabling technologies and R&D: descriptive statistics

Technology 4.0	Average	Std. Dev.	Min	Max	ER Average	Veneto Average
TECH 4.0 (dummy)	0.412	0.492	0	1	0.391	0.427
Nr. TECH 4.0	1.353	0.702	1	5	1.424	1.306
IoT	0.088	0.283	0	1	0.102	0.077
ROBOT	0.120	0.325	0	1	0.115	0.124
BIG DATA	0.039	0.195	0	1	0.036	0.042
AR/VR	0.005	0.071	0	1	0.005	0.006

CYBERSECURITY	0.048	0.215	0	1	0.056	0.043
AI	0.006	0.076	0	1	0.008	0.004
3D PRINTING	0.048	0.214	0	1	0.045	0.050
CLOUD	0.044	0.205	0	1	0.040	0.046
OTHER	0.159	0.366	0	1	0.151	0.165
R&D						
R&D (dummy)	0.227	0.420	0	1	0.230	0.227
R&D/turnover| R&D=1	0.063	0.075	0.01	0.55	0.065	0.062
R&D (employ.)|R&D=1	6.190	14.19	0	211.7	4.444	7.450

Table 4.5 shows that the main source of funding for innovative activity is internal company resources, followed at some distance by ordinary bank loans. On average, only 4% say they have used public funds or incentives, while the percentage of companies that use other means of financing is negligible.

Table 4.5. Financing sources: descriptive statistics

Financing	Average	Std. Dev.	Min	Max	ER Average	Veneto Average
Internal resources	0.422	0.494	0	1	0.370	0.459
Ordinary loan	0.141	0.349	0	1	0.143	0.140
Dedicated loan	0.009	0.095	0	1	0.009	0.009
Shares	0.002	0.044	0	1	0.003	0.001
Public funds	0.041	0.198	0	1	0.036	0.044
Other	0.004	0.062	0	1	0.005	0.003

Finally, the last section of the questionnaire is dedicated to the degree of importance that the firm attributes to the following factors in dealing with crises caused by external shocks such as pandemics, inflation, and availability of raw materials: new products or services offered; new production processes; the quality of the product/service offered; the quality of the production process; innovations to reduce environmental impact; employee training; reduction of production costs; reduction of personnel costs; reduction of R&D investments; reduction of investments in innovations to reduce environmental impact; other factors. For each item, a response of 1 is associated with "not at all important", while a response of 4 is associated with "very important". For the econometric analysis, we defined a series of binary variables that take the value 1 if the firm assigns a degree of importance to each item of at least 3. Table 4.6 shows that, on average, most of the surveyed firms identify the quality of the products offered and the containment of production costs as the most strategic factors, while the least popular are the reduction in innovative investments. Finally, it is interesting to note that all average percentage values are higher in Veneto than in Emilia-Romagna.

Table 4.6. Innovation variables: descriptive statistics

Strategies	Average	Std. Dev.	Min	Max	ER Average	Veneto Average
NEW PRODUCTS	0.617	0.486	0	1	0.593	0.633
NEW PROCESSES	0.561	0.496	0	1	0.530	0.583
PRODUCT QUALITY	0.833	0.373	0	1	0.811	0.849
PROCESS QUALITY	0.755	0.430	0	1	0.738	0.768
ENVIRONMENTAL INNOVATION	0.567	0.496	0	1	0.534	0.590
TRAINING	0.735	0.442	0	1	0.734	0.735
PRODUCTION COSTS	0.811	0.392	0	1	0.792	0.824
LABOUR COSTS	0.562	0.496	0	1	0.539	0.579
R&D INVESTMENTS	0.311	0.463	0	1	0.292	0.324
ENVIRONMENT INVESTMENT	0.345	0.476	0	1	0.321	0.362
OTHER	0.267	0.442	0	1	0.253	0.276

The empirical model and econometric estimation strategy

The next step is to define an empirical model with which to analyse the relationship between these three types of factors and the propensity of firms to innovate. A reference model is represented by the knowledge production function, a relationship that links the processes and activities through which new knowledge, information, and skills are generated, developed, and disseminated within an organisational or economic context. Specifically, to understand how much new technological knowledge is generated by a company, the knowledge production function uses key input variables such as R&D, human capital, tangible and intangible assets, innovation diffusion mechanisms linked to networking activities, and the technology available to the company itself.

Referring to the available data, the model that is subjected to empirical verification is as follows:

$$\Pr(Y_i = 1|\mathbf{X_i}) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_k x_{ki} + \varepsilon_i,$$

where Y represents the innovative output variable of firm i, β_0 is a constant term; $x_1, x_2, \ldots, x_k$ represent the k explanatory variables (which define the vector $\mathbf{X}$) representing the general characteristics, technological endowment, sources of financing of the firm and its post-pandemic strategies; $\beta_1, \beta_2, \ldots, \beta_k$, represent the k parameters to be estimated, whose sign and statistical significance will indicate the relevance of the underlying factor for the company's innovative activity; finally, the term ε represents the stochastic error term, with zero mean and constant variance. The above equation is estimated using a linear probability model with robust standard errors for heteroscedasticity. Furthermore, in order to test for the presence of any multicollinearity, we will perform a VIF (variance inflation factor) test, in which a test statistic value below the threshold of 5 will indicate the absence of this problem. It should be noted that the estimation of the β coefficients does not imply any causal relationship between the variables, but only a correlation between them.

As the first set of dependent variables, we consider the dummy variables INNOPROD, INNOPROC, and INNOORG, i.e., the variables that measure whether the firm introduced a new product, a new process, or a new organisational practice in 2020-22. Next, we will distinguish product innovations by their degree of novelty, i.e., INCREMENTAL or RADICAL, and then consider the demand for

PATENTS, also distinguishing those that have reduced the environmental impact of the firm itself (GREEN PATENTS). Finally, we will focus on the set of variables that measure circular innovation, distinguishing appropriately by their purpose, i.e., REDUCTION, RECYCLING and REUSE.

The explanatory variables used in the model are divided into three groups. The characteristics of the firm considered include: size, in terms of number of employees as at 31/12/2020; age, calculated by subtracting the year of foundation from 2022; whether it is family-owned; membership of an industrial group (national or international) or a production chain; the signing of a network contract; location in an industrial district, as defined by ISTAT; quality certifications, such as ISO9001, ISO14011, ISO45001 or SA8000; management structure, with the presence of women, young people, or graduates; the main reference market, whether local, regional, national or international. To these, we add a dummy variable to distinguish firms located in Emilia-Romagna (value 1) from those located in Veneto (value 0). The second group of variables includes those relating to technological equipment and R&D. Concerning enabling technologies, we used two different sets of variables: the first is Nr. TECH4.0, i.e., how many types of 4.0 technological tools the company uses in 2020-22; the second is the entire group of 4.0 technologies, measured using the corresponding dummy variables. While the first variable aims to capture the possible impact that the synergy, or combination, of different technologies can have on the propensity to innovate, the second aims to identify the relationship that innovation has with each technological component. In addition to these, we also include the R&D intensity variable, measured by its share of the company's turnover. The third group of regressors includes variables that capture the means used by firms to finance their innovative activities. As shown in Table 4.5, these means range from the use of the firm's own resources to ordinary or dedicated bank loans, to the use of public funds, to less frequent means such as the issuance of shares or other channels. Finally, the fourth group of variables concerns the strategies considered most important for dealing with situations of crisis or economic and financial stress. These strategies range from innovation and product or process quality to cost and investment containment, as shown in Table 4.6.

Table 4.7 shows the results of the first linear regressions on the probability of innovating with new products, processes, or organisational models. Concerning product innovation, there is a positive and statistically significant correlation with firm size and its propensity to supply national or international markets. Among the technology variables, only the R&D coefficient stands out, which, as expected, is the highest and statistically significant at 1%. Among the means of financing, the most frequent ones, such as own resources and ordinary bank loans, are significantly correlated. Finally, as might be expected, the probability of generating new products is directly correlated with a business strategy that sees product innovation as the key to overcoming periods of crisis. It should also be noted that the VIF statistic is always well below 5, so we can disregard multicollinearity as a potential problem for the estimates.

Regarding the variables significantly correlated with a higher propensity for process innovation, we again include size, quality certifications, and a lower propensity to serve foreign markets, probably because they are more stimulating for product innovation. The role of 4.0 technologies, on the other hand, now emerges as relevant: the introduction of new production processes is stimulated both by the number of technological assets adopted and by certain individual enabling technologies, such as robotics, the use of big data and data analytics, artificial intelligence, and the use of cloud computing systems. Two other differences compared to product innovation concern financing and business strategies: on the first front, we note that the spectrum of significant sources of financing extends to public funds and other unspecified forms, while in the second case, the orientation towards the introduction of new production processes clearly emerges.

Finally, firms with a greater propensity for organisational innovation are, on average, larger, operate within production chains, have quality certifications, and use 4.0 technologies, especially software for big data analysis and cloud computing. As with process innovation, there are many relevant sources of funding, not only linked to internal resources or ordinary bank loans, while it is interesting to note that, at a strategic level, there is a significant focus on new processes and staff training.

Table 4.7. General propensity for innovation

	(1)	(2)	(3)	(4)	(5)	(6)
Characteristics	INNOPROD		INNOPROC		INNOORG	
Emilia-Romagna	-0.006	-0.006	0.002	0.003	0.007	0.008
	(0.017)	(0.017)	(0.017)	(0.017)	(0.018)	(0.018)
$EMPLOYEES_{2020}$	0.000**	0.000*	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AGE	-0.000	-0.000	0.000	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FAMILY ORG.	0.027	0.026	0.009	0.004	-0.014	-0.017
	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.019)
GROUP	0.043	0.043	-0.018	-0.026	-0.004	-0.012
	(0.028)	(0.029)	(0.030)	(0.031)	(0.031)	(0.031)
SUPPLY CHAIN	0.002	0.004	0.016	0.017	0.057**	0.056**
	(0.026)	(0.026)	(0.025)	(0.025)	(0.027)	(0.028)
NETWORK	0.028	0.026	-0.033	-0.014	0.047	0.055
	(0.043)	(0.043)	(0.044)	(0.042)	(0.041)	(0.041)
DISTRICT	-0.029	-0.029	-0.059	-0.051	-0.036	-0.034
	(0.039)	(0.039)	(0.043)	(0.044)	(0.043)	(0.043)
CERTIFICATION	-0.011	-0.008	0.033*	0.037**	0.037*	0.041**
	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.019)
WOMEN MNG	-0.002	0.000	0.020	0.023	0.004	0.005
	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.019)
YOUNG MNG	0.010	0.009	0.010	0.009	0.034	0.038
	(0.025)	(0.025)	(0.024)	(0.024)	(0.026)	(0.026)
GRADUATED MNG	-0.018	-0.020	-0.016	-0.017	0.029	0.025
	(0.018)	(0.018)	(0.019)	(0.019)	(0.019)	(0.019)
REG MARKET	0.023	0.024	0.021	0.022	-0.026	-0.019
	(0.032)	(0.032)	(0.029)	(0.029)	(0.029)	(0.029)
NAT MARKET	0.070**	0.067**	-0.004	-0.007	-0.023	-0.026
	(0.031)	(0.031)	(0.030)	(0.031)	(0.033)	(0.033)
EXT MARKET	0.174***	0.172***	-0.109***	-0.109***	-0.020	-0.018
	(0.036)	(0.036)	(0.039)	(0.040)	(0.038)	(0.038)
Technology						
Nr. TECH 4.0	0.021		0.080***		0.062***	
	(0.014)		(0.013)		(0.013)	
IoT		0.011		0.042		0.032
		(0.036)		(0.039)		(0.039)
ROBOT		0.000		0.105***		0.016
		(0.031)		(0.029)		(0.033)
BIGDATA		0.087		0.120**		0.151***
		(0.054)		(0.052)		(0.051)
AR/VR		0.151		-0.113		-0.131
		(0.102)		(0.105)		(0.114)
CYBER		0.013		0.015		0.047
		(0.046)		(0.052)		(0.053)

AI		-0.016		0.224***		0.116
		(0.092)		(0.065)		(0.122)
STAMPA 3D		0.035		0.006		0.022
		(0.042)		(0.049)		(0.051)
CLOUD		-0.035		0.123**		0.151***
		(0.054)		(0.050)		(0.054)
R&D/TURNOVER	1.317***	1.331***	0.183	0.200	0.202	0.206
	(0.227)	(0.230)	(0.249)	(0.246)	(0.272)	(0.269)
Financing						
INT. RESOURCES	0.557***	0.559***	0.550***	0.557***	0.487***	0.490***
	(0.024)	(0.024)	(0.023)	(0.023)	(0.024)	(0.024)
LOAN	0.226***	0.228***	0.354***	0.362***	0.287***	0.299***
	(0.037)	(0.037)	(0.036)	(0.036)	(0.036)	(0.037)
BOND	0.147	0.160	0.089	0.065	0.083	0.069
	(0.095)	(0.098)	(0.147)	(0.145)	(0.154)	(0.154)
PUBLIC	0.057	0.059	0.156**	0.170**	0.122*	0.121*
	(0.070)	(0.070)	(0.068)	(0.068)	(0.070)	(0.070)
OTHER	0.140	0.143	0.446*	0.459*	0.633***	0.653***
	(0.205)	(0.209)	(0.263)	(0.269)	(0.134)	(0.137)
Strategies						
NEW PROD	0.086***	0.086***	-0.071***	-0.067***	-0.037*	-0.032
	(0.022)	(0.022)	(0.021)	(0.021)	(0.021)	(0.021)
NEW PROC	-0.030	-0.031	0.083***	0.079***	0.094***	0.094***
	(0.022)	(0.022)	(0.023)	(0.023)	(0.023)	(0.022)
QUAL PROD	-0.015	-0.014	-0.007	-0.011	0.014	0.008
	(0.028)	(0.028)	(0.030)	(0.030)	(0.030)	(0.030)
QUAL PROC	0.006	0.008	0.017	0.020	-0.021	-0.015
	(0.026)	(0.026)	(0.027)	(0.027)	(0.026)	(0.026)
ENVIRONMENTAL	0.019	0.017	-0.030	-0.031	-0.040*	-0.043**
INNOVATION	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
TRAINING	0.015	0.016	0.033	0.033	0.051**	0.048**
	(0.022)	(0.022)	(0.023)	(0.023)	(0.023)	(0.023)
PROD COST	-0.025	-0.027	0.008	0.012	0.007	0.009
	(0.025)	(0.024)	(0.025)	(0.025)	(0.026)	(0.026)
LABOUR COST	-0.002	-0.003	-0.004	-0.010	-0.013	-0.015
	(0.021)	(0.020)	(0.021)	(0.021)	(0.022)	(0.022)
R&D COST	0.008	0.009	0.017	0.012	-0.016	-0.018
	(0.029)	(0.029)	(0.026)	(0.026)	(0.028)	(0.028)
ENVIRONMENTAL	0.007	0.006	0.038	0.046*	0.016	0.023
COST	(0.028)	(0.028)	(0.025)	(0.025)	(0.027)	(0.027)
Costant	-0.044	-0.042	-0.024	-0.015	-0.032	-0.027
	(0.032)	(0.032)	(0.033)	(0.033)	(0.033)	(0.032)
N	1549	1549	1549	1549	1549	1549
R^2	0.540	0.542	0.529	0.529	0.462	0.466
VIF average	1.32	1.29	1.32	1.29	1.32	1.29
VIF max	2.07	2.08	2.07	2.08	2.07	2.08

Standard errors robust to heteroscedasticity in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

It should be noted that the empirical model does not include, among the possible explanatory variables, the location of the company in the various provinces available, and the sector to which it belongs. This is because the inclusion of province and/or sector dummies would create significant

multicollinearity problems, as evidenced by VIF test values well above 10, distorting the estimated coefficients.

Table 4.8. Degree of novelty of new products

	(1)	(2)	(3)	(4)
Characteristics	INCREMENTAL		RADICAL	
Emilia-Romagna	-0.010	-0.011	0.005	0.005
	(0.019)	(0.019)	(0.016)	(0.016)
$EMPLOYEES_{2020}$	-0.000	-0.000	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
AGE	0.000	0.000	-0.001	-0.001
	(0.000)	(0.001)	(0.000)	(0.000)
FAMILY ORG.	0.036*	0.034*	-0.009	-0.009
	(0.020)	(0.020)	(0.017)	(0.017)
GROUP	0.053	0.046	-0.010	-0.004
	(0.033)	(0.034)	(0.029)	(0.029)
SUPPLY CHAIN	0.005	0.005	-0.003	-0.001
	(0.029)	(0.029)	(0.025)	(0.026)
NETWORK	-0.004	0.000	0.033	0.026
	(0.047)	(0.047)	(0.039)	(0.039)
DISTRICT	0.005	0.006	-0.035	-0.036
	(0.045)	(0.045)	(0.038)	(0.038)
CERTIFICATION	-0.012	-0.009	0.001	0.001
	(0.020)	(0.020)	(0.017)	(0.017)
WOMEN MNG	-0.015	-0.016	0.012	0.016
	(0.020)	(0.020)	(0.017)	(0.017)
YOUNG MNG	0.007	0.007	0.003	0.002
	(0.027)	(0.027)	(0.023)	(0.023)
GRADUATED MNG	0.003	0.003	-0.021	-0.023
	(0.021)	(0.021)	(0.017)	(0.017)
REG MARKET	-0.002	-0.001	0.024	0.025
	(0.031)	(0.031)	(0.023)	(0.023)
NAT MARKET	0.024	0.021	0.046*	0.046*
	(0.034)	(0.034)	(0.026)	(0.026)
EXT MARKET	0.003	0.008	0.171***	0.164***
	(0.041)	(0.041)	(0.036)	(0.036)
Technlogies				
Nr. TECH 4.0	0.009		0.012	
	(0.015)		(0.014)	
IoT		-0.034		0.045
		(0.044)		(0.037)
ROBOT		0.009		-0.009
		(0.035)		(0.030)
BIGDATA		0.055		0.032
		(0.072)		(0.053)
AR/VR		-0.009		0.160
		(0.160)		(0.114)
CYBER		0.057		-0.044
		(0.061)		(0.053)
AI		0.106		-0.121
		(0.142)		(0.117)
STAMPA 3D		-0.063		0.099*
		(0.055)		(0.051)

CLOUD		-0.049		0.014
		(0.064)		(0.053)
R&D/TURNOVER	0.015	0.038	1.303***	1.293***
	(0.296)	(0.295)	(0.276)	(0.273)
Financing				
INT. RESOURCES	0.355***	0.360***	0.202***	0.199***
	(0.025)	(0.025)	(0.020)	(0.019)
LOAN	0.143***	0.147***	0.083***	0.081***
	(0.038)	(0.038)	(0.030)	(0.030)
BOND	0.158	0.158	-0.011	0.002
	(0.147)	(0.142)	(0.113)	(0.108)
PUBLIC	0.023	0.033	0.035	0.025
	(0.073)	(0.073)	(0.058)	(0.057)
OTHER	0.125	0.125	0.015	0.018
	(0.173)	(0.173)	(0.142)	(0.140)
Strategies				
NEW PROD	0.015	0.014	0.071***	0.073***
	(0.023)	(0.023)	(0.019)	(0.019)
NEW PROC	-0.003	-0.005	-0.028	-0.026
	(0.024)	(0.024)	(0.021)	(0.021)
QUAL PROD	-0.003	0.000	-0.012	-0.015
	(0.032)	(0.032)	(0.026)	(0.026)
QUAL PROC	0.001	-0.001	0.005	0.009
	(0.029)	(0.028)	(0.024)	(0.024)
ENV INNO	0.001	0.001	0.018	0.016
	(0.023)	(0.023)	(0.019)	(0.019)
TRAINING	0.004	0.005	0.011	0.011
	(0.024)	(0.024)	(0.020)	(0.020)
PROD COST	-0.028	-0.029	0.002	0.003
	(0.028)	(0.028)	(0.022)	(0.022)
LABOUR COST	0.031	0.030	-0.032*	-0.033*
	(0.023)	(0.023)	(0.020)	(0.019)
R&D COST	-0.007	-0.008	0.015	0.017
	(0.030)	(0.030)	(0.025)	(0.025)
ENV COST	0.015	0.017	-0.008	-0.010
	(0.029)	(0.030)	(0.025)	(0.025)
Constant	-0.003	0.003	-0.041	-0.046
	(0.034)	(0.034)	(0.028)	(0.028)
N	1549	1549	1549	1549
R^2	0.238	0.241	0.233	0.240

Standard errors robust to heteroscedasticity in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The next step is to distinguish product innovations by degree of novelty, i.e., incremental (referring to products that are new to the company alone) and radical (referring to products that are new to the sector/market or to the world). Table 4.8 shows that, for incremental innovation, there are few statistically significant estimated coefficients, and these mostly refer to traditional means of financing. The picture is different for radical innovations, where it emerges that these are the preserve of larger companies, those more exposed to foreign markets, those more equipped with smart manufacturing technologies such as 3D printers, those more intensive in R&D investment and those more oriented towards giving great importance to the introduction of new products and little importance to reducing labour costs within their business strategies.

Table 4.9 presents the results of estimates regarding the propensity of companies to apply for or file patents over the three years.

Table 4.9. Patents and green patents

	(1)	(2)	(3)	(4)
Caratteristiche	PATENTS		GREEN PATENTS	
Emilia-Romagna	0.003	0.002	-0.001	-0.002
	(0.013)	(0.013)	(0.006)	(0.005)
$EMPLOYEES_{2020}$	0.000	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
AGE	0.000	0.000	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)
FAMILY ORG.	0.006	0.004	0.002	0.001
	(0.014)	(0.014)	(0.006)	(0.006)
GROUP	0.074***	0.068***	0.007	0.001
	(0.027)	(0.026)	(0.012)	(0.012)
SUPPLY CHAIN	-0.020	-0.015	0.010	0.011
	(0.018)	(0.018)	(0.010)	(0.011)
NETWORK	-0.025	-0.028	-0.012	-0.010
	(0.026)	(0.026)	(0.011)	(0.010)
DISTRICT	-0.028	-0.029	-0.001	-0.001
	(0.030)	(0.030)	(0.016)	(0.016)
CERTIFICATION	0.015	0.018	-0.003	-0.002
	(0.013)	(0.013)	(0.007)	(0.006)
WOMEN MNG	-0.021	-0.018	-0.008	-0.007
	(0.013)	(0.013)	(0.006)	(0.006)
YOUNG MNG	0.021	0.021	0.016	0.017*
	(0.018)	(0.018)	(0.010)	(0.010)
GRADUATED MNG	0.013	0.011	-0.007	-0.007
	(0.015)	(0.014)	(0.006)	(0.006)
REG MARKET	0.021	0.024*	0.005	0.006
	(0.014)	(0.014)	(0.006)	(0.006)
NAT MARKET	0.022	0.018	-0.000	-0.002
	(0.019)	(0.019)	(0.008)	(0.007)
EXT MARKET	0.195***	0.191***	0.032**	0.033**
	(0.032)	(0.031)	(0.015)	(0.015)
Technlogies				
Nr. TECH 4.0	0.035***		0.015**	
	(0.012)		(0.008)	
IoT		0.047		0.019
		(0.032)		(0.019)
ROBOT		-0.023		-0.004
		(0.023)		(0.012)
BIGDATA		0.069		0.029
		(0.051)		(0.027)
AR/VR		0.103		-0.031*
		(0.140)		(0.017)
CYBER		0.042		0.021
		(0.048)		(0.024)
AI		0.225		0.195
		(0.139)		(0.129)
STAMPA 3D		0.122**		0.003
		(0.048)		(0.021)

CLOUD		-0.040		0.003
		(0.039)		(0.020)
R&D/TURNOVER	0.730***	0.702***	0.378**	0.377***
	(0.236)	(0.234)	(0.150)	(0.145)
Financing				
INT. RESOURCES	0.032**	0.034**	-0.001	0.001
	(0.014)	(0.014)	(0.006)	(0.006)
LOAN	0.011	0.022	-0.010	-0.005
	(0.023)	(0.023)	(0.011)	(0.010)
BOND	-0.073	-0.067	-0.040***	-0.048**
	(0.084)	(0.089)	(0.014)	(0.020)
PUBLIC	-0.020	-0.019	0.028	0.030
	(0.045)	(0.044)	(0.030)	(0.030)
OTHER	-0.100*	-0.090*	-0.012	-0.007
	(0.052)	(0.053)	(0.017)	(0.017)
Strategies				
NEW PROD	0.038***	0.038***	0.011**	0.011**
	(0.014)	(0.014)	(0.005)	(0.005)
NEW PROC	-0.010	-0.009	-0.002	-0.003
	(0.017)	(0.016)	(0.007)	(0.006)
QUAL PROD	-0.016	-0.017	-0.021*	-0.021*
	(0.019)	(0.019)	(0.011)	(0.011)
QUAL PROC	0.018	0.020	0.011	0.010
	(0.018)	(0.017)	(0.007)	(0.007)
ENV INNO	0.024	0.023	0.012*	0.013*
	(0.015)	(0.015)	(0.006)	(0.007)
TRAINING	-0.035**	-0.035**	-0.003	-0.005
	(0.016)	(0.016)	(0.006)	(0.007)
PROD COST	-0.010	-0.011	-0.002	-0.002
	(0.017)	(0.017)	(0.008)	(0.008)
LABOUR COST	0.006	0.007	0.002	0.002
	(0.015)	(0.015)	(0.007)	(0.007)
R&D COST	0.014	0.015	-0.005	-0.005
	(0.017)	(0.017)	(0.007)	(0.006)
ENV COST	-0.012	-0.013	-0.003	-0.002
	(0.017)	(0.017)	(0.009)	(0.009)
Costant	-0.039*	-0.038*	-0.014	-0.011
	(0.022)	(0.022)	(0.012)	(0.012)
N	1549	1549	1549	1549
R^2	0.147	0.163	0.077	0.093

Standard errors robust to heteroscedasticity in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The propensity to patent is positively associated with belonging to an industrial group and the company's presence in foreign markets. As might be expected, the intensity of R&D is very significant, but so is technological endowment. Among the individual enabling technologies, 3D printing stands out, clearly linked to prototyping activities before the creation of a patent. For patents aimed at reducing the environmental impact of the company, we can see that, among the drivers, the presence of young managers and the age of the company emerge (albeit weakly significant). Finally, it is interesting to note that both propensities to patent increase with the importance of strategies related to both the introduction of new products and environmental innovation.

Let us now analyse the factors linked to the introduction of innovations geared towards the principles of the circular economy, distinguishing between the three main methods inspired by the 3R model: reduction, recycling, and reuse.

Table 4.10. Circular innovations

Caratteristiche	(1) CIRC INNO	(2) CIRC INNO	(3) INNO REDUCE	(4) INNO REDUCE	(5) INNO RECYCLE	(6) INNO RECYCLE	(7) INNO REUSE	(8) INNO REUSE
Emilia-Romagna	-0.038**	-0.038**	-0.044**	-0.045**	-0.004	-0.006	-0.011	-0.011
	(0.018)	(0.018)	(0.018)	(0.018)	(0.016)	(0.016)	(0.017)	(0.017)
$EMPLOYEES_{2020}$	-0.000***	-0.000***	-0.000***	-0.000***	-0.000	-0.000	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AGE	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001**	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FAMILY ORG.	0.024	0.022	0.015	0.011	0.001	-0.005	0.016	0.016
	(0.019)	(0.019)	(0.019)	(0.019)	(0.017)	(0.017)	(0.017)	(0.017)
GROUP	0.056*	0.058*	0.038	0.037	0.018	0.010	0.068**	0.072**
	(0.030)	(0.031)	(0.032)	(0.032)	(0.029)	(0.029)	(0.031)	(0.031)
SUPPLY CHAIN	0.030	0.032	0.052*	0.055**	0.085***	0.078***	0.027	0.023
	(0.026)	(0.026)	(0.027)	(0.027)	(0.027)	(0.027)	(0.026)	(0.026)
NETWORK	-0.028	-0.024	-0.014	-0.011	-0.078**	-0.072**	0.038	0.037
	(0.041)	(0.041)	(0.041)	(0.041)	(0.036)	(0.036)	(0.043)	(0.043)
DISTRICT	0.085**	0.087**	0.097**	0.099**	-0.009	-0.011	0.034	0.032
	(0.039)	(0.039)	(0.041)	(0.041)	(0.039)	(0.039)	(0.041)	(0.041)
CERTIFICATION	0.027	0.028	0.046**	0.048***	0.027	0.026	0.000	-0.003
	(0.018)	(0.018)	(0.018)	(0.019)	(0.018)	(0.017)	(0.017)	(0.017)
WOMEN MNG	0.057***	0.060***	0.053***	0.056***	0.033*	0.034*	0.044**	0.047**
	(0.019)	(0.019)	(0.019)	(0.019)	(0.018)	(0.018)	(0.018)	(0.018)
YOUNG MNG	0.081***	0.078***	0.064**	0.060**	0.012	0.009	0.045*	0.043*
	(0.024)	(0.024)	(0.025)	(0.025)	(0.024)	(0.024)	(0.025)	(0.025)
GRADUATED MNG	-0.004	-0.003	-0.001	-0.000	0.002	0.001	0.009	0.009
	(0.019)	(0.019)	(0.020)	(0.020)	(0.018)	(0.018)	(0.019)	(0.018)
REG MARKET	0.014	0.015	0.047*	0.047*	0.008	0.010	-0.015	-0.014
	(0.029)	(0.029)	(0.028)	(0.029)	(0.026)	(0.026)	(0.026)	(0.026)
NAT MARKET	0.021	0.021	0.046	0.044	-0.014	-0.017	0.040	0.044
	(0.031)	(0.031)	(0.031)	(0.031)	(0.029)	(0.029)	(0.029)	(0.029)
EXT MARKET	0.008	0.005	0.029	0.025	0.004	0.008	0.093**	0.090**
	(0.038)	(0.039)	(0.038)	(0.038)	(0.035)	(0.035)	(0.037)	(0.037)
Technlogies								
Nr. TECH 4.0	0.051***		0.057***		0.049***		0.045***	
	(0.014)		(0.014)		(0.014)		(0.015)	
IoT		0.069*		0.086**		0.051		0.080**
		(0.038)		(0.041)		(0.041)		(0.040)
ROBOT		0.063**		0.060*		0.077**		0.061*
		(0.031)		(0.034)		(0.033)		(0.032)
BIGDATA		0.045		0.054		0.132**		-0.032
		(0.055)		(0.062)		(0.059)		(0.059)
AR/VR		0.079		0.131		-0.038		-0.014
		(0.095)		(0.114)		(0.115)		(0.123)
CYBER		0.003		0.036		0.108*		0.041
		(0.054)		(0.058)		(0.058)		(0.061)
AI		-0.032		0.058		-0.061		-0.203**
		(0.131)		(0.138)		(0.126)		(0.087)
STAMPA 3D		0.014		0.017		-0.088*		0.012
		(0.047)		(0.051)		(0.047)		(0.050)
CLOUD		0.057		-0.005		0.048		0.147**

		(0.055)		(0.058)		(0.058)		(0.063)
R&D/TURNOVER	0.473**	0.489**	0.452*	0.466*	0.400	0.414	0.432*	0.409
	(0.240)	(0.242)	(0.246)	(0.250)	(0.274)	(0.275)	(0.261)	(0.264)
Financing								
INT. RESOURCES	0.469***	0.474***	0.340***	0.347***	0.246***	0.247***	0.222***	0.221***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.021)	(0.021)	(0.021)	(0.021)
LOAN	0.339***	0.340***	0.349***	0.351***	0.106***	0.102***	0.121***	0.120***
	(0.035)	(0.036)	(0.035)	(0.036)	(0.033)	(0.032)	(0.033)	(0.034)
BOND	-0.150	-0.148	-0.103	-0.095	0.013	0.018	-0.213*	-0.213*
	(0.157)	(0.162)	(0.150)	(0.156)	(0.113)	(0.118)	(0.123)	(0.123)
PUBLIC	0.222***	0.227***	0.119*	0.128*	0.070	0.076	0.227***	0.228***
	(0.054)	(0.055)	(0.066)	(0.067)	(0.058)	(0.058)	(0.065)	(0.064)
OTHER	0.149	0.151	0.181	0.181	0.002	0.009	-0.014	-0.009
	(0.291)	(0.296)	(0.281)	(0.287)	(0.194)	(0.203)	(0.188)	(0.192)
Strategies								
NEW PROD	0.010	0.013	0.012	0.014	-0.011	-0.010	0.032	0.036*
	(0.022)	(0.022)	(0.023)	(0.023)	(0.021)	(0.021)	(0.021)	(0.020)
NEW PROC	0.005	0.004	0.021	0.020	0.037*	0.036	-0.013	-0.010
	(0.023)	(0.023)	(0.024)	(0.024)	(0.022)	(0.022)	(0.022)	(0.022)
QUAL PROD	-0.016	-0.018	-0.046	-0.045	0.052**	0.053**	0.020	0.016
	(0.030)	(0.030)	(0.031)	(0.031)	(0.024)	(0.024)	(0.027)	(0.026)
QUAL PROC	-0.018	-0.016	-0.018	-0.018	-0.020	-0.021	-0.020	-0.018
	(0.026)	(0.026)	(0.028)	(0.028)	(0.023)	(0.023)	(0.025)	(0.025)
ENV INNO	0.077***	0.075***	0.085***	0.084***	0.077***	0.074***	0.078***	0.077***
	(0.021)	(0.021)	(0.022)	(0.022)	(0.019)	(0.019)	(0.020)	(0.020)
TRAINING	-0.035	-0.035	-0.025	-0.025	-0.036*	-0.038*	-0.025	-0.026
	(0.023)	(0.023)	(0.023)	(0.023)	(0.020)	(0.020)	(0.021)	(0.021)
PROD COST	0.020	0.022	0.031	0.032	-0.034	-0.033	-0.024	-0.020
	(0.025)	(0.025)	(0.025)	(0.025)	(0.023)	(0.023)	(0.023)	(0.023)
LABOUR COST	-0.023	-0.026	-0.034	-0.037*	-0.009	-0.012	-0.008	-0.009
	(0.021)	(0.021)	(0.022)	(0.022)	(0.021)	(0.020)	(0.021)	(0.021)
R&D COST	0.022	0.022	0.009	0.010	0.035	0.034	-0.026	-0.028
	(0.027)	(0.027)	(0.027)	(0.027)	(0.026)	(0.026)	(0.025)	(0.025)
ENV COST	-0.021	-0.019	-0.011	-0.010	-0.023	-0.019	0.033	0.035
	(0.027)	(0.027)	(0.027)	(0.027)	(0.026)	(0.026)	(0.026)	(0.026)
Costant	-0.076**	-0.071**	-0.104***	-0.096***	-0.108***	-0.093***	-0.101***	-0.096***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.030)	(0.030)	(0.031)	(0.031)
N	1549	1549	1549	1549	1549	1549	1549	1549
R^2	0.495	0.493	0.412	0.410	0.250	0.262	0.267	0.275

Standard errors robust to heteroscedasticity in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Columns 1 and 2 of Table 4.10 reveal some noteworthy evidence. For the first time, we note that in Veneto there is a generally greater propensity to innovate circularly, as the estimated coefficient of the Emilia-Romagna dummy is negative and statistically significant at 5%. Among the structural characteristics, we see that those significantly correlated with INNO CIRC are smaller company size, age, membership of an industrial group, location in an industrial district, and management composition, specifically the employment of women and young people. Therefore, unlike the general propensity to innovate, a clear picture emerges of the circular innovation enterprise: small, mature, district-based, part (as a supplier) of a larger group, and with young and female management. Technological endowment also seems to be particularly relevant: we note that both the number of enabling technologies adopted and specific technologies such as IoT and robotics are important. In terms of financing, not only are traditional private channels significantly relevant, but also public ones, while among corporate strategies, only the importance of environmental innovation emerges as a way of dealing with periods of crisis and economic difficulty.

Distinguishing between the three categories of circular innovation, as shown in columns 3-8, we note some interesting differences regarding the drivers associated with them. First of all, the greater propensity for innovation among Veneto companies seems to apply only to innovation aimed at reducing raw materials or energy. We also note that the smaller size of the plants does not seem to influence innovation aimed at recycling, unlike age, which is always a significant factor for every type of circular innovation. Belonging to an industrial group is only significant in the case of product reuse, while belonging to a production chain seems particularly relevant in the case of innovation aimed at recycling. Even location in an industrial district, as well as possession of quality certifications, seems to be a relevant factor in only one out of three cases, that of raw material reduction. It is also interesting to note that the presence of women and young people in the company's management is almost always a relevant factor for the introduction of circular innovations, almost as if to testify to the recent and, if you will, disruptive nature of these strategies. Finally, among the characteristics, we note that only in the case of INNO RIUSO is the reference market coefficient, specifically the foreign market, statistically significant.

The picture becomes more interesting when we analyse the role of 4.0 technologies for circular innovation, from a twin transition perspective. First, it emerges that the estimated coefficient of Nr. TECH4.0 is always positive and highly significant. Columns 2, 4, 6, and 8 show that robotics is a technology that cuts across all types of circular innovation, slightly more relevant for innovations aimed at material recycling. IoT is the other technology that seems to play a significant role in increasing the likelihood of circular innovation, specifically in terms of reducing raw materials and reusing products. In this regard, IoT devices can collect real-time data on product conditions and performance, enabling predictive maintenance, where potential problems are identified and resolved before they lead to failures, thus extending product life. In addition, sensors embedded in products can monitor various parameters (e.g., temperature, humidity, pressure) and provide feedback on product conditions. This information can help users take steps to maintain and care for the product, ensuring it functions properly for a longer period. IoT devices can also track how products are used: this data can inform manufacturers about common usage patterns and wear points, which can be addressed in future designs to improve durability. In short, the IoT can track the entire life cycle of a product, from production to disposal. This data can facilitate better end-of-life management, including recycling and reuse of components, by providing detailed information on the materials and components used in the product. Finally, we note that big data and the cloud are two additional technologies that facilitate the introduction of innovations aimed at recycling materials, while the cloud, unlike artificial intelligence, is useful for increasing product durability by facilitating real-time data analysis and storage, facilitating the use of machine learning models, and the simulation and testing of new products or prototypes.

With regard to financing, estimates reveal the cross-cutting importance of using internal company resources and traditional bank loans, but also the importance of public funds and incentives, which are always relevant except in the case of innovations aimed at recycling materials/products. Finally, among the strategies, the focus on environmental innovation is almost always the only relevant variable, together with product quality, for innovations aimed at recycling materials/products.

5. Conclusions

This report aims to illustrate the main results emerging from the sample survey *Circular Economy – UNIPD – PNRR*, whose questionnaire was administered using CATI and CAWI methods in autumn 2023 to a representative sample of 1,549 manufacturing companies located in Emilia-Romagna and Veneto and active in the three years 2020-2022.

The survey, structured in sections, provides a range of information on the structural characteristics of the companies, their general innovative activity, the circular innovations introduced, and the enabling technologies used in the three years and in previous periods. Finally, a specific set of questions is dedicated to the importance of innovative strategies for dealing with periods of economic crisis due to external shocks such as pandemics, inflation, and wars.

The results of the report show that, in the two regions, about one-third of the surveyed firms have introduced new products or processes oriented towards the principles of the circular economy and the 3Rs. The aspects that seem most frequently correlated with the propensity to innovate are size, exposure to foreign markets, technological equipment, more traditional forms of financing, and the importance of certain business strategies aimed precisely at innovation.

In terms of employment, the picture that emerges from the data is ambivalent: while, on the one hand, it is generally larger firms that innovate, on the other hand, it is smaller ones that innovate in a circular sense, probably a sign of their greater flexibility in achieving energy saving, material and product reuse, or waste cycle reduction objectives. Another noteworthy finding is that a greater propensity for circular innovation is correlated with the presence of women and young people in the firm's management. Exports, or at least having foreign markets as the main target market, represent an important element of comparison and learning for the firm, often linked to the introduction of new products, even of a radical nature, or patents.

Technological equipment and investment in R&D are among the most interesting and relevant drivers, especially from the perspective of the *twin transition.* The survey reveals that not only individual technologies, but also their overall provision, can help companies in their innovation efforts. Econometric estimates, therefore, reveal a significant relationship between digital technologies and environmental innovations, with technologies such as robotics, IoT, big data/data analytics, and cloud computing standing out among the former. Artificial intelligence and the metaverse (or augmented and virtual reality) appear to be less influential, probably due to their low level of adoption among firms.

Among the means of financing, the use of internal resources and ordinary bank loans recur in all regressions as factors positively correlated with the propensity to innovate, while other channels are almost always insignificant. This evidence reflects the still traditional structure of financial relations, where recourse to (international) capital markets and venture capital is still limited, and where Italian entrepreneurs' risk aversion and their willingness to keep control of the company within the founding families is still historically high.

Finally, a look at recent international crises due to the pandemic, wars, energy crises, and the resulting inflation shows us that what correlates with a higher propensity to innovate, even in a circular sense, is precisely the orientation of firms towards new products and environmental innovation itself. On the other hand, there is no link between innovation and more defensive strategies that place a high importance on containing production costs, labour costs, or R&D investments.

Appendix

Table A1 - Comparison of survey distribution with Infocamere register - Veneto

ATECO	Survey (%)	Infocamere (%)	ATECO (2-digits)	Survey (%)	Infocamere (%)
10 - Food industry	3.76	6.18	22 – Manufacture of rubber and plastic products	5.41	2.85
11 – Beverage industry	0.66	0.78	23 – Manufacture of other non-metallic mineral products	4.64	4.56
12 – Tobacco industry	0	0.05	24 – Metallurgy	1.44	0.81
13 – Textile industries	2.98	2.38	25 – Manufacture of metal products (excluding machinery and equipment)	27.40	19.70
14 - Manufacture of clothing; manufacture of leather and fur goods	4.97	10.22	26 – Manufacture of computers and electronic and optical products; electromedical apparatus, measuring apparatus and watches	1.99	1.65
15 - Manufacture of leather and related products	5.75	4.57	27 – Manufacture of electrical equipment and non-electrical household appliances	4.20	3.22
16 – Wood and wood and cork products industry (excluding furniture); manufacture of straw and woven goods	4.64	6.34	28 – Manufacture of machinery and equipment n.e.c..	10.50	7.28
17 – Manufacture of paper and paper products	1.66	1.00	29 – Manufacture of motor vehicles, trailers and semi-trailers	0.66	0.73
18 – Printing and reproduction of recorded media	2.32	2.94	30 – Manufacture of other transport equipment	0.88	1.05
19 – Manufacture of coke and products derived from oil refining	0.11	0.09	31 – Furniture manufacturing	5.75	7.13
20 – Manufacture of chemical products	1.77	1.17	32 – Other manufacturing industries	4.09	7.87
21 – Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.11	0.25	33 – Repair, maintenance and installation of machinery and equipment	4.20	7.18

Table A2 - Comparison of survey distribution with Infocamere register – Emilia-Romagna

ATECO	Survey (%)	Infocamere (%)	ATECO (2-digits)	Survey (%)	Infocamere (%)
10 - Food industry	7.30	10.37	22 – Manufacture of rubber and plastic products	5.59	2.61
11 – Beverage industry	0.78	0.45	23 – Manufacture of other non-metallic mineral products	3.11	3.46
12 – Tobacco industry	0	0	24 – Metallurgy	1.55	0.66
13 – Textile industries	1.09	2.85	25 – Manufacture of metal products (excluding machinery and equipment)	34.01	22.98
14 - Manufacture of clothing; manufacture of leather and fur goods	2.17	9.82	26 – Manufacture of computers and electronic and optical products; electromedical apparatus, measuring apparatus and watches	2.17	2.52
15 - Manufacture of leather and related products	0.93	1.99	27 – Manufacture of electrical equipment and non-electrical household appliances	3.26	2.76
16 – Wood and wood and cork products industry (excluding furniture); manufacture of straw and woven goods	2.48	4.33	28 – Manufacture of machinery and equipment n.e.c..	15.22	9.58
17 – Manufacture of paper and paper products	1.71	0.94	29 – Manufacture of motor vehicles, trailers and semi-trailers	1.40	1.12
18 – Printing and reproduction of recorded media	2.02	2.9	30 – Manufacture of other transport equipment	0.16	1.04
19 – Manufacture of coke and products derived from oil refining	0	0.1	31 – Furniture manufacturing	2.02	3.16
20 – Manufacture of chemical products	1.40	1.4	32 – Other manufacturing industries	2.80	6.24
21 – Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.16	0.26	33 – Repair, maintenance and installation of machinery and equipment	7.92	8.47

Table A3 - Distribution of firms by 3-digit ATECO sectors in Veneto

ATECO (3-digit)	Freq (%)	ATECO (3-digit)	Freq (%)	ATECO (3-digit)	Freq (%)	ATECO (3-digit)	Freq (%)
101	0.44	181	2.32	245	0.44	283	0.66
102	0.22	192	0.11	251	7.40	284	0.99
103	0.22	201	0.22	252	0.44	289	3.31
105	0.33	202	0.11	255	1.44	291	0.11
106	0.44	203	0.55	256	11.16	292	0.22
107	1.55	204	0.66	257	2.32	293	0.33
108	0.33	205	0.22	259	4.64	301	0.22
109	0.22	212	0.11	261	0.88	302	0.22
110	0.66	221	0.11	263	0.33	309	0.44
132	0.33	222	5.30	264	0.11	310	5.75
133	0.77	231	1.10	265	0.33	321	1.33
139	1.88	232	0.22	266	0.33	323	0.11
141	4.20	234	0.44	271	1.44	324	0.11
143	0.77	236	0.88	273	0.44	325	1.55
151	2.98	237	1.44	274	0.44	329	0.99
152	2.76	239	0.55	275	0.44	331	2.10
161	0.99	241	0.22	279	1.44	332	2.10
162	3.65	242	0.11	279	1.44	452	0.11
171	0.22	243	0.55	281	0.88		
172	1.44	244	0.11	282	4.64		

Table A4 Distribution of firms by 3-digit ATECO sectors in Emilia-Romagna

ATECO (3-digit)	Freq (%)	ATECO (3-digit)	Freq (%)	ATECO (3-digit)	Freq (%)	ATECO (3-digit)	Freq (%)
101	2.33	201	0.31	251	7.14	283	1.55
105	0.78	203	0.31	252	1.09	284	1.09
106	0.31	204	0.16	255	0.78	289	3.88
107	2.80	205	0.47	256	20.81	291	0.16
108	0.93	206	0.16	257	1.71	292	0.16
109	0.16	212	0.16	259	2.02	293	1.09
110	0.78	221	0.47	260	0.16	309	0.16
130	0.16	222	5.12	261	0.62	310	2.02
131	0.16	231	0.31	262	0.31	321	0.47
133	0.16	232	0.16	264	0.31	323	0.16
139	0.62	233	0.93	265	0.31	325	1.86
141	1.24	234	0.31	266	0.31	329	0.31
143	0.93	236	0.78	267	0.16	331	4.19
151	0.31	237	0.16	271	1.24	332	3.73
152	0.62	239	0.47	273	0.78	463	0.16
161	0.31	241	0.16	274	0.62	467	0.16
162	2.17	242	0.31	275	0.16	478	0.16
171	0.16	243	0.16	279	0.47	620	0.16
172	1.55	245	0.93	281	1.86	741	0.16
181	2.02	250	0.47	282	6.83		

Table A5 - Circular innovation categories

Reduction in water use in the production process	I1
Reduction in the use of raw materials (including energy)	I2
Product changes to minimise the use of materials	I3
Use of energy from renewable sources	I4
Reduction in electricity generated from non-renewable sources	I5
Increased product durability	I6
Measures to facilitate the disassembly of components	I7
Possibility of product repair	I8
Change in product design to maximise recyclability	I9
Replacement of materials with high environmental impact with sustainable materials	I10
Reduction in waste emitted (per unit of output produced)	I11
Reuse of waste in the own production cycle	I12
Transfer of own waste to other companies, which use it in their own production cycle	I13