UNIVERSITÀ POLITECNICA DELLE MARCHE

FACOLTÀ DI ECONOMIA "GIORGIO FUÀ"

Master's Degree in

INTERNATIONAL ECONOMICS AND COMMERCE

The effects of digitalization strategies on sustainable well-being of the Italian provinces: a PoSet approach.

Supervisor: Prof. Mariateresa Ciommi

Candidate: Chiara Lella

Academic Year 2023 – 2024

INDEX

Introduction

The increase in conflicts and wars in the world, the increase of social injustices perpetrated especially against the weakest categories of the population (women, the elderly, children and the disabled), the constant worsening of climatic and environmental conditions on a global scale have led the United Nations to define, as part of the so-called "2030 Agenda", a series of sustainable development goals that every nation on the planet must commit to achieve.

The achievement of the 17 goals defined by the 2030 Agenda is quantified by a series of indicators that are collected at European level by Eurostat and at national level by ISTAT. The availability of these indices makes it possible to carry out various studies that make it possible to assess the effectiveness of certain development strategies adopted at local and national level.

The most recent research seems to confirm the close link between the digitalization of organizations and sustainable growth, as defined in the context of the 2030 Agenda. A bond so close that it has led to the coining of the new term "digitainability", the union between digitalization and sustainability.

The aim of this thesis is to identify a methodology for the study of digitainability on a regional, provincial and national scale, which can be taken as a reference and allows not only to draw up an accurate ranking of the progress achieved in the field of digitalization for sustainable development, but also to evaluate the effectiveness of the measures taken by local policy makers in the context of digitization strategies undertaken on the territory. Starting from the definition of the 17 sustainable growth goals (SDGs) defined by the UN and listed in chapter 1, the main organizations committed to achieving these goals are then presented, together with the development programs and strategies they have prepared. We then proceed with the examination of the sets of indicators implemented and kept constantly updated that make it possible to monitor the achievement of the objectives of the 2030 Agenda.

Through the methodology of studying partially ordered systems, the only one that can allow objective studies on the phenomenon of digitainability, some interesting results are presented that allow us to draw initial conclusions on the effects of the strategies undertaken by the provincial policy makers.

Chapter 1

DIGITAINABILITY

1.1 Digitalization

"Organisational digitalization refers to the adoption and integration of digital technologies within an organization's practices, processes, and business models.

This process not only involves the use of digital tools and platforms, but also the transformation of organizational structures and cultures to optimize efficiency, productivity and innovation."

According to Schwab: “Organisational digitisation involves the integration of digital technologies into all aspects of the organisation, leading to fundamental changes in operational processes and the delivery of value to customers. It is not just about adopting new technologies, but rethinking the way an organisation works and interacts with the market and its customers”.

Klaus Schwab is the founder and current Executive Chairman of the World Economic Forum (WEF) based in Geneva and the author of the book “The fourth industrial revolution”.

According to Markku Kuusisto (2017) “digitalization refers to usage of any digital assets organizations can use to improve their performance and the effects of these technologies have had on how the world works”.

The major impact of digitalization on organizations is that information is more accessible and transparent. Digitalization has made it much easier to make information available for all personnel, who have previously been working with limited knowledge of the big picture of the business. This allows employees to make more informed decisions at lower levels of the organization. Business Intelligence (BI) programs are made to analyze and compress data for top management – a task previously done manually by middle management. Together these assist in making modern organizations flatter with fewer hierarchies than before (Dewett and Jones, 2001).

Knowledge silos usually consist of deeply trained specialists in one field. However, these silos are being brought down by the organizational changes driven by digitalization. This is a directresult of knowledge being distributed more and more efficiently – and the need for lean and agile organizations that are able to perform different actions in quick succession. Contemporary organizations believe information sharing is the key to success. This is enforced via various platforms, enabling employees to gain knowledge of the status of the company – online screens, intranets and more recently social media, are among the ways companies keep their staff up to date (McAfee, 2006).

1.2 Sustainable Development Goals

To address the economic, environmental, social and health emergencies being experienced on a global scale, 17 Sustainable Development Goals (SDGs) were defined in 2015 by the United Nations Organization to be achieved by 2030. All 193 countries belonging to the United Nations, including Italy, are called upon to actively adhere to the 2030 Agenda, which is developed into 169 targets or goals associated with the 17 SDGs, to be achieved in the environmental, economic, social and institutional spheres (Chamber of Deputies, 2022).

The 17 SDGs are globally valid, and affect all components of society, from private companies to the public sector, from civil society to institutional referents and even information and culture operators. They have been broken down as follows:

 **Goal 1 - End Poverty**: Eradicate extreme poverty for all people everywhere.

 **Goal 2 - Defeat hunger**: Ensure all people have access to sufficient, safe, and nutritious food.

Goal 3 - Health and well-being: Ensure healthy lives and promote well-being for all at all ages.

Goal 4 - Quality education: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Goal 5 - Gender equality: Achieve gender equality and empower all women and girls.

Goal 6 - Clean water and sanitation: Ensure availability and sustainable management of water and sanitation for all.

Goal 7 - Affordable and clean energy: Ensure access to affordable, reliable, sustainable, and modern energy for all.

Goal 8 - Decent work and economic growth: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.

Goal 9 - Enterprise, innovation and infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.

Goal 10 - Reduce inequalities: Reduce inequality within and among countries.

Goal 11 - Sustainable cities and communities: Make cities and human settlements inclusive, safe, resilient, and sustainable.

Goal 12 - Responsible consumption and production: Ensure sustainable consumption and production patterns.

Goal 13 - Fight against climate change: Take urgent action to combat climate change and its impacts.

Goal 14 - Life below water: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

Goal 15 - Life on Earth: Protect, restore, and promote sustainable use of terrestrial ecosystems, manage forests sustainably, combat desertification, halt and reverse land degradation, and halt biodiversity loss.

Goal 16 - Peace, justice and strong institutions: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.

Goal 17 - Partnership for the Goals: Strengthen the means of implementation and revitalize the global partnership for sustainable development.

The approach adopted is holistic, recognizing that sustainable development requires simultaneous interventions in multiple areas with integrated and concrete solutions. A recent UN progress report on the 2030 Agenda indicates that, halfway to the target date, more than half of the goals remain unmet globally, particularly in social, environmental, and health sectors. The COVID-19 pandemic, climate change, biodiversity loss, and increased global pollution have significantly impeded progress. The conflicts in Ukraine and Palestine have further hindered the Agenda's goals, with the war in Ukraine creating a humanitarian crisis and deteriorating the global economy, especially impacting developing and least developed countries.

1.2.1 *Global and European context*

Developing countries have been most affected, but developed nations also face increased public debt due to expansionary fiscal and monetary policies adopted to manage the ensuing economic crises. The UN High-Level Political Forum (HLPF) assesses annual progress and organizes a comprehensive review every four years at the UN General Assembly. Voluntary national reviews (NRVs) facilitate experience sharing and underpin HLPF reviews to accelerate the 2030 Agenda's implementation.

Figure 1 – EU Strategic Agenda 2019-2024

Source: European Commission

The European Union (EU) is committed to the 2030 Agenda's sustainable development goals, aligning them with the 2015 Paris Agreement. The EU has led in combating climate change, developing policies for the circular economy, research and innovation, social inclusion, biodiversity protection, and sustainable agriculture. The European Commission has integrated the 2030 Agenda into EU decision-making, launching the Green Deal for Europe, a strategy to make Europe the first carbon-neutral continent by 2050, along with other initiatives under the EU Strategic Agenda 2019-2024.

The Commission has set out a roadmap of policies and measures needed to deliver the Green Deal, involving all sectors of the economy. Aiming for climate neutrality by 2050, it has proposed the "Fit for 55%" package to reduce greenhouse gas emissions by 55% by 2030 compared to 1990 levels. This target is binding under the European Climate Law.

The Cohesion Funds are crucial in supporting regions and rural areas, and the new Just Transition Fund will aid populations and regions most affected by the transition. Public funding must be complemented by actions to stimulate private investment through green finance strategies and an investment plan for a sustainable Europe. Part of the European Investment Bank will be transformed into a European Climate Bank.

Each country can decide how to incorporate these objectives into policies and decision-making, defining its own national sustainable development strategy. National parliaments play a key role in producing legislation, adopting budgets, and implementing programs. In Italy, the "Benessere Italia" Steering

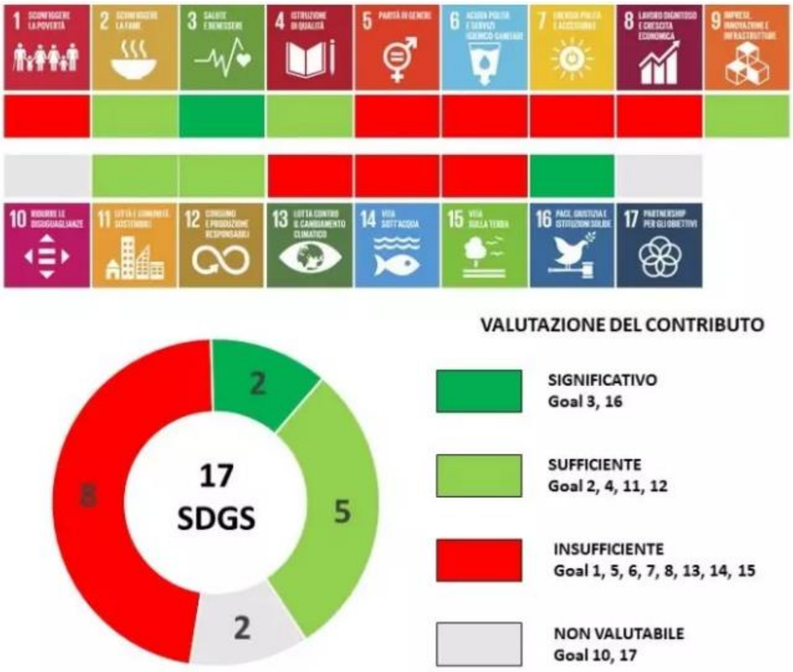
Committee was established in 2019 to coordinate and monitor policies across Ministries to improve citizens' well-being. The Ministry of Ecological Transition was created in 2021, merging functions of the Ministry of the Environment and the Ministry of Economic Development to handle sustainable development. The Interministerial Committee for Ecological Transition (ISCED) coordinates national policies for ecological transition.

Italy's government program is developed around five macro-areas: equitable sustainable regeneration of territories, mobility and territorial cohesion, energy transition, quality of life, and circular economy. These translate into the "5Ps" of the National Sustainable Development Strategy (SNSvS): People, Planet, Prosperity, Peace, and Partnership. The SNSvS integrates sustainability into national policies, plans, and projects but does not provide quantitative parameters for the 2030 Agenda's objectives.

The SNSvS is linked with the National Reform Programme (PNRR) and the Economic and Financial Document (DEF) and is updated every three years after consultations. The Italian Alliance for Sustainable Development (ASviS) monitors progress towards the 2030 Agenda and the SDGs.

To address the 2020 pandemic's effects, the SNSvS was integrated with the National Recovery and Resilience Plan (PNRR). The PNRR utilizes funds from the Next Generation EU (NGEU), with Italy as the first beneficiary. The PNRR, divided into six Missions and sixteen Components, includes reforms in public administration, justice, legislative simplification, and competition promotion. Environmental protection, poverty, gender equality, and labour protection are inadequately addressed. ASviS proposes a multidimensional approach to SDG1 (No Poverty) that improves services and increases incomes. For SDG5 (Gender Equality), equal opportunities at work and women's leadership must be promoted.

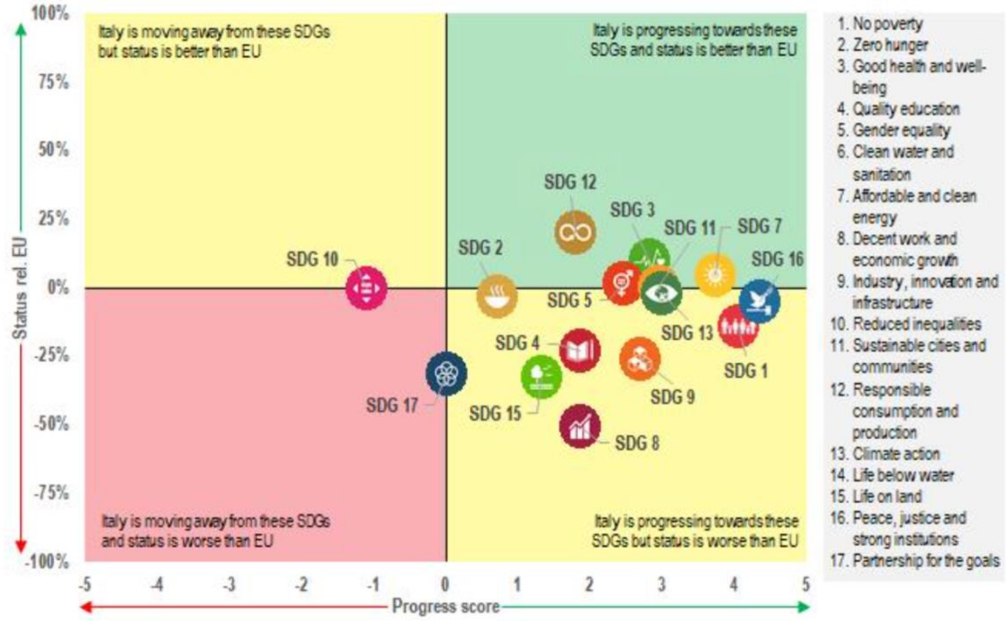
Figure 2: Contribution of the Italian PNRR to the 2030 Agenda



Source: ASviS

Environmental SDGs 6, 7, 13, 14, and 15 require a systemic vision of water resources, aquatic ecosystems, and climate change. The poorest should be exempt from paying for water, electricity, and gas. At least 37% of resources should go to climate action, and tax reforms including a carbon tax should be implemented. Coastal marine areas need better protection, overexploitation of fish stocks should end, and all degraded ecosystems should be restored by 2030.

Figure 3 : Achievement of the 2030 Agenda goals. Italy's performance



Source: European Commission Italy 2022 Country Report (page 23)

For SDG8 (Decent Work), the PNRR does not adequately address full employment, with NEETs at over 23% in 2020, while the EU target is 9% by 2030. ASviS suggests updating the SNSvS and revising the CIPE to focus on sustainability and proposes a constitutional reform to include environmental protection. The EU has urged Italy to revise the PNRR, adding 145 measures including justice reforms, company incentives, renewable energy investments, and subsidies for flood-affected regions. EU funding for the PNRR will increase to €194.4 billion. A 2023 Eurostat report assesses Italy's SDG progress using indicators up to 2022.

For each indicator, a country's score is calculated on a scale from worst to best performing in the EU, using a min-max normalisation technique. All the scores obtained were aggregated to derive the score of the EU average for each SDG, in order to show as a percentage how much in percentage, relative to each SDG, each country deviates from the EU average. These values made it possible to obtain the table of the progress of all EU countries, including that of Italy shown in figure 3. It is found that all the indicators related to the SDGs of our country are improving, with the exception of the indicator related to the availability and sustainable management of water and sanitation, which in any case has a value that is above the EU average. On 5 of the remaining 16 indicators (ensuring health and well-being for all and all ages; promoting peaceful and inclusive societies; ensuring access to affordable, reliable, sustainable and modern energy systems for all; ensuring sustainable production and consumption patterns; conserving and sustainably using the oceans, seas and marine resources for sustainable development), Italy's performance is not only growing, but also exceeds the level of EU media.

This result is confirmed by a recent ISTAT report (2023), now in its sixth edition. As can be seen in figure 4, compared to the previous 10 years, ISTAT has in fact estimated that 58.6% of the measures related to the SDGs are improving, 21.3% are stationary and only 20.1% report a worsening as a result of the persistence of the economic and financial crisis linked to the continuation of the pandemic and the outbreak of the conflict in Ukraine. In SDGs 5,7,8, 12, 16 and 17, three-quarters or more of the related measures show a positive change, while in SDGs 2,4,11 and 13 more than a third of the indicators worsen.

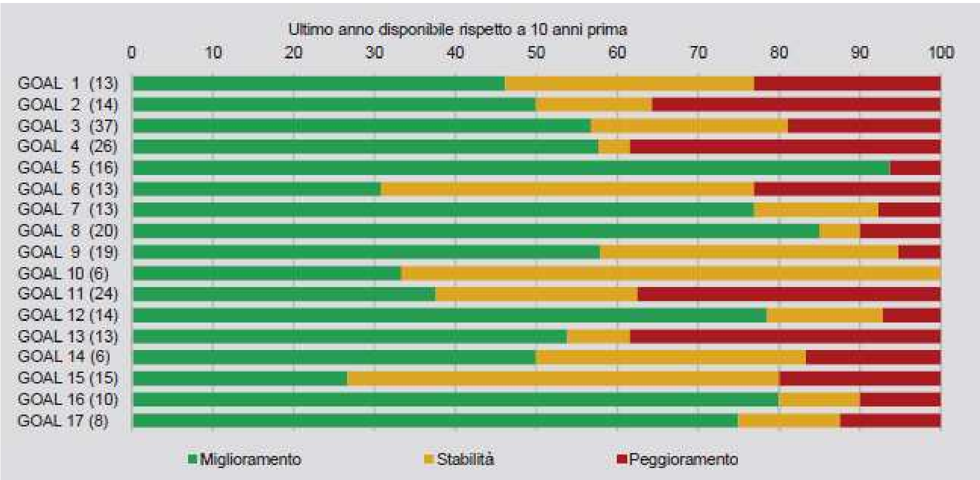
Figure 4: Evolution of statistical measures related to the SDGs in Italy over 10 years

REGIONI	Livello di sviluppo sostenibile					Totale indicatori disponibili
	basso	medio-basso	medio	medio-alto	alto	
Piemonte	5,2	15,7	28,8	34,0	16,3	153
Valle d'Aosta/*Vallée d'Aoste*	15,3	16,0	14,7	24,0	30,0	150
Liguria	7,7	14,1	38,5	27,6	12,2	156
Lombardia	9,8	8,5	19,6	34,0	28,1	153
Bolzano/*Bozen*	13,7	13,7	13,1	17,0	42,5	153
Trento	5,9	9,8	16,3	29,4	38,6	153
Veneto	7,1	14,1	30,1	29,5	19,2	156
Friuli-Venezia Giulia	5,2	16,8	20,6	34,8	22,6	155
Emilia-Romagna	9,0	12,2	21,8	34,6	22,4	156
Toscana	1,9	17,3	34,6	32,7	13,5	156
Umbria	4,6	16,3	26,8	32,0	20,3	153
Marche	3,2	14,7	30,1	34,6	17,3	156
Lazio	9,0	23,2	27,7	27,1	12,9	155
Abruzzo	5,1	25,6	34,6	26,3	8,3	156
Molise	11,5	23,1	27,6	19,9	17,9	156
Campania	32,7	28,2	16,0	13,5	9,6	156
Puglia	9,6	43,6	24,4	14,1	8,3	156
Basilicata	22,4	25,0	21,2	16,0	15,4	156
Calabria	39,1	16,7	17,3	16,7	10,3	156
Sicilia	40,4	23,1	16,7	13,5	6,4	156
Sardegna	16,0	31,4	21,2	17,3	14,1	156

Source: Report SDGs 2022 (page 12)

There is a certain positive correlation between the share of measures improving and the share of measures converging on a territorial scale. Finally, Figure 6 shows the levels of measures related to the SDGs divided into five homogeneous groups on the different Italian regions and areas. This analysis, also retrieved from the latest ISTAT report, relates to the last available year (2024).

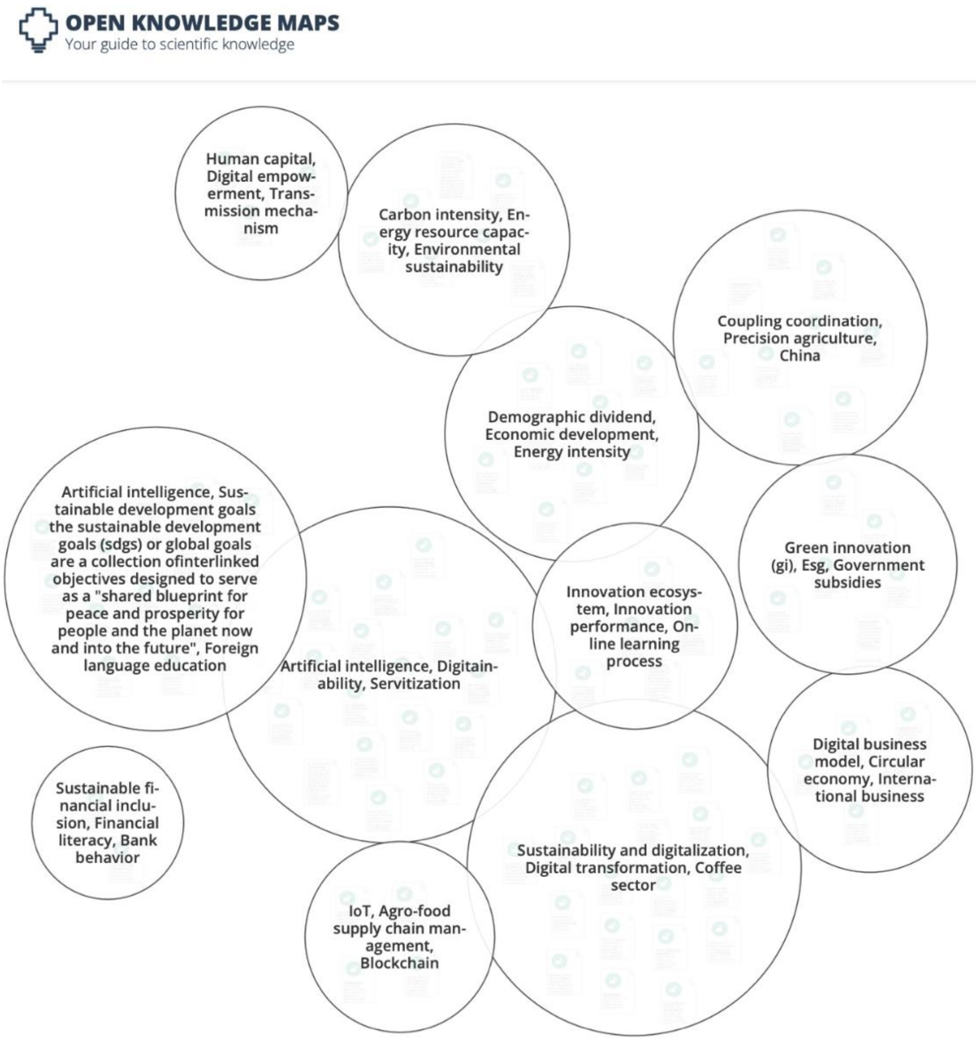
Figure 5: Measures related to the SDGs by region and geographical distribution in Italy



Source: Report SDGs 2024 (page 12)

The aim of this thesis is not to identify a set of indicators, alternative to those identified by ISTAT and Eurostat, that quantify the degree of achievement of the SDGs, but to identify a subset of indicators among those taken into consideration at provincial level, together with an analysis technique applicable to them, to assess the effect of digitalisation on achieving sustainable growth goals.

Figure 6 - Concept map of the Openknowledgemaps



Source: outcome of the Openknowledgemaps search on 15th April 2024

1.2.2 *Digitalisation and complementary factors*

The digitalization of the country is one of the 5 Missions of the PNRR as it is rightly considered an enabling factor for the growth of the country's sustainable well-being. Digitalization, to show its full effectiveness, both in the organizational and social spheres, both in the private and public sectors, must be accompanied by complementary activities that essentially concern the dissemination of new ICT and the development of human capital.

The Organisation for Economic Co-operation and Development (OECD) has collected in a single publication (OECD, 2004) all the evidence concerning the phenomenon of digitalisation.

The OECD defines ICT as “products intended to fulfill or enable the function of information processing and communications by electronic means, including transmission and display”.

First of all, it has been found that the more people and organizations are involved in the diffusion of new ICTs, the greater the benefits that can be achieved. Directly related to the economic development of a country is also the size of the ICT sector. The higher the number of companies operating in the IT sector, the greater the growth of a country over time, especially if these companies provide support to the e-commerce, finance and B2B services sector. The size of the companies that are digitized also matters a lot. Small organizations tend to take less advantage of the benefits of digitalization.

The development of new online services must also be accompanied by an increase in the levels of security of online communications and transactions. The deregulation of the electronic market also allows digitalisation to have greater effects on economic growth. Nations such as the United States, Canada, New Zealand, Australia and the Northern European States have achieved remarkable results in terms of the development of their economies precisely by acting on these particular aspects (Pilat and Devlin, 2004).

Countries that have not yet adapted have to face not only the costs of technological updating (in terms of the acquisition of new ICT equipment, strengthening of the telecommunications network with broadband, creation of digital services), but also organizational costs, related to the development of know-how and the acquisition of qualified personnel with flexible forms of work that can also lead to the growth of the organization's innovative potential from the This increases the possibilities for organizations to absorb new ICT knowledge to improve their processes or the quality of their products and services.

It is important to accompany the training adaptation and the campaigns of new hires with the adoption of new working practices such as team-working, job rotation, the awarding of multi-skilling, the involvement of the customer in project activities and the narrowing of the hierarchical structure. The phenomenon of spill-over, i.e. the "contamination of ideas" resulting from innovation favored by such working practices, leads to the start-up of new companies that are immediately digitized (Pilat and Devlin, 2004, Hollenstein, 2004). Other articles published in (OECD, 2004) focus on the impact of ICT at the organizational level, not considering aggregated data but evaluating the effect of digitalization within each individual company. In particular, the increase in business productivity is most recorded in the financial and insurance sector, closely followed by the cultural and recreational services sector (Gretton et al., 2004).

The article by Milana and Zeli (2004) analyzes the causes of the slowdown in industrial production in the early 2000s in our country to understand whether digitalization can actually contribute to a revival of our economy. The study covered all Italian companies with at least 20 employees until 1997 and those with at least 100 employees from 1998 to 2004. Specifically, the trend in total factor productivity (TFP) was analysed, which reflects the overall efficiency with which primary inputs, labour and capital, are used in the production process. The growth in TFP therefore indicates a higher level of output per hour worked. It has been shown that the decrease in industrial production has been of a structural nature, linked to the lack of timely technological updating. The use of new ICTs has led to an increase in TFP over time.

1.3 *Digitainability – a literature overview.*

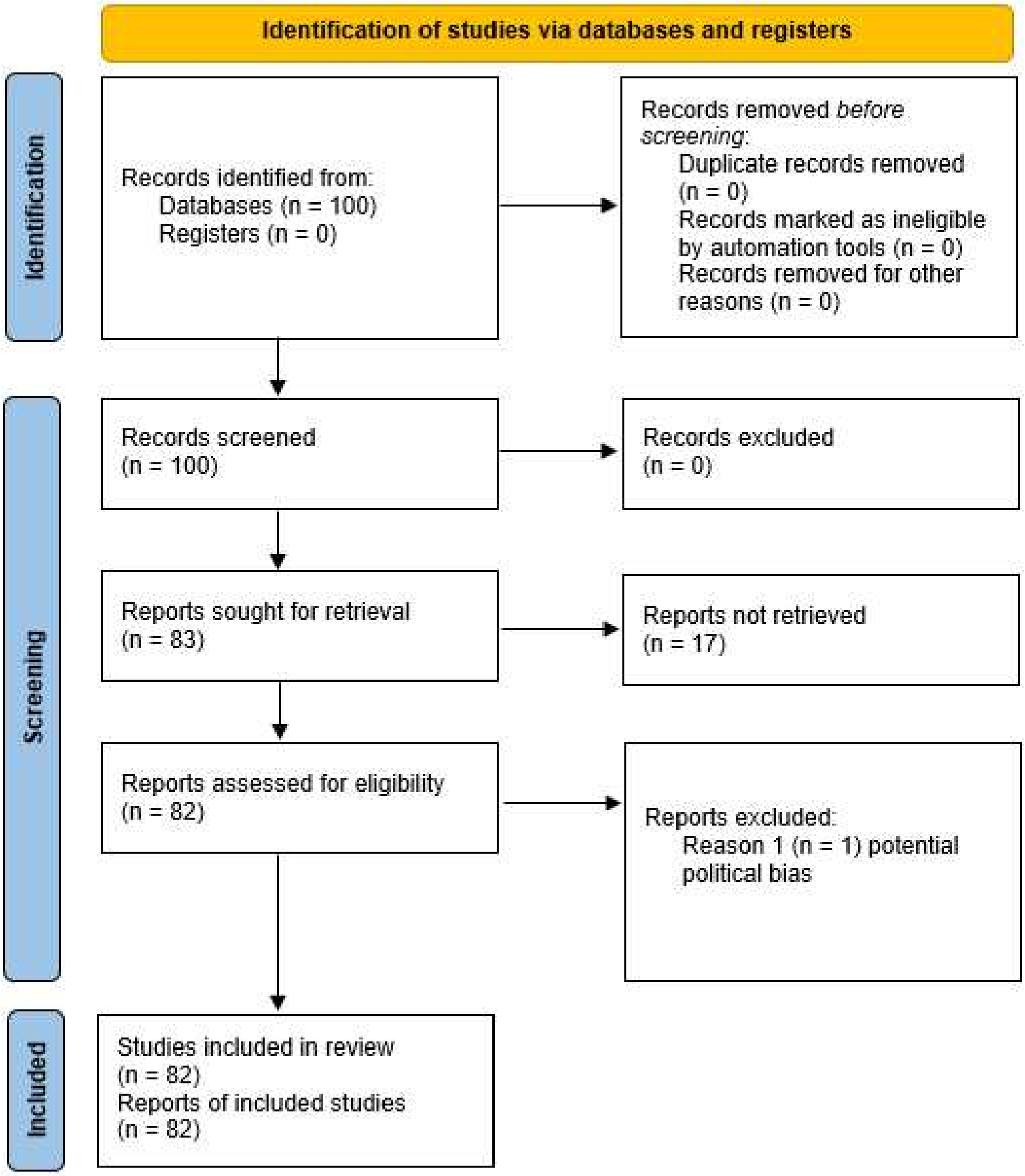
To analyse the link between digitalisation and sustainable development, a study of systematic reviews using the PRISMA 2020 method was conducted (Page et al., 2021). To find the sources of information, openknowledgemaps was used, a search engine based on an AI model that can be freely consulted and distributed by the Know Center of Graz (Austria), a non-profit organization and European leader in innovation and research for the development of reliable AI in data science.

Figure 7 shows the outcome of the search carried out on the Web by the openknowledgemaps engine, which retrieved the 100 articles it considered most related to the query "digitalization effects on sustainable development" from 37 different publishers. The result of this query was published under the CC BY 4.0 DEED Attribution 4.0 International license, and is reproduced here without modification.

As shown in figure 7, it was not possible to retrieve 17 of the 100 articles identified by openknowledgemaps. Full-text analysis of the remaining 83 papers led to the exclusion of only one article from the study, as the conclusions drawn from it were potentially influenced by political bias.

The remaining 82 articles are considered bias-free, as pointed out by the authors themselves in the final self-declaration.

Figure 7 - Articles identified by Openknowledgemaps



Source: outcome of the Openknowledgemaps search on 15th April 2024

According to a study conducted by Sobalkar and Anekar, the digitalization process mainly affects three of the seventeen Sustainable Development Goals. In particular, SDG 4 (quality education), SDG 3 (health and well-being) and

SDG 9 (business, innovation and infrastructure), which showed a correlation score with digitalisation of 73%, 71% and 65% respectively. According to the authors, this means that even modest progress in the digitalization process can lead to significant progress in the three aforementioned SDGs. However, it remains a problem, especially in developing countries, to find accessible and up-to-date data that will allow the progress of these Sustainable Development Goals to be constantly monitored.

In fact, the categorization of the articles selected for full-text review seems to confirm the result of Sobalkar and Anekar, even if the interest of the research seems to have focused more on the study of the impact of digitalization on SDG 9 (business, innovation and infrastructure), to which 31 of the 82 articles analyzed can be associated, immediately followed by the impact on SDG 3 (health and well-being), with 26 articles judged to be related, the impact on SDG 4 (quality education) and SDG 2 (eradicate hunger) with both 23 related articles and the impact on SDG 11 (sustainable cities and communities) with 21 related articles. A smaller number of articles also analysed the effects on SDG 12 (responsible consumption and production with 19 related articles), SDG 8 (decent work and economic growth with 17 related articles), SDG 7 (affordable and clean energy with 16 related articles) and SDG 13 (climate action with 15 related articles).

As far as the research centers and organizations of the authors of the analyzed articles are concerned, the majority are located in the East (especially China) and in the Middle East with 52 articles. In second place are researchers working in Europe with 39 papers. On the other hand, researchers belonging to Australian (5 articles), North American (3 articles) and South American (2 articles) organizations or research centers are poorly represented by this study. Researchers from the East and the Middle East are most interested in the impact of digitalisation on innovation, competitiveness, culture and tourism (30 articles), the impact on the green revolution and ecological transition (28 articles) and the impact on levels of inclusion and social cohesion (17 articles). European researchers are most interested in the impact of digitalisation on innovation, competitiveness, culture and tourism (27 articles), the impact on the green revolution and ecological transition (19 articles), the impact on education and research (16 articles) and the impact on levels of inclusion and social cohesion (15 articles). The close link between digitalization and sustainable development has led to the emergence of the term "digitainability" in the scientific literature. According to Lichtenthaler (2021), there is a close link between the two megatrends of digitalization in companies and their sustainable development. However, even though digitalization is a key focus in the strategic planning of almost all of the organizations analyzed, many of them can still be considered at the beginning of the transformation process. “To denote the intricate relationship between Digitalization and Artificial Intelligence (D&AI), on the one hand, and sustainability, on the other hand, we have coined the noun “digitainability”, a merging of the terms “digitalization” and “sustainability”. It refers to the cross-fertilization between the processes of digitalization and sustainable Development” (Gupta et al. 2020). Other authors (Tu et al., 2023; Camodeca and Almici, 2021, Bican and Brem, 2020) believe that digitalization plays a vital role in achieving all the SDGs, approaching in particular the heart of these goals which is given by solving the environmental and economic problems of the various countries. Digitalization, by facilitating the planning of activities, monitoring, evaluation and re-engineering of processes, can in fact contribute to lowering the environmental impact of companies and establishing a virtuous circular economy process with interesting returns, including economic ones (D'Amico et al., 2023; Tokhir, 2023; Esses et al., 2021;). Technologies such as the Internet of Things (IoT), smart grids, GPS tracking systems, blockchain can develop and strengthen the circularity of economic, social and environmental resources as long as the active involvement of all stakeholders involved in achieving the digital sustainable growth goals is pursued (D'Amico et al, 2023; Villamil et al. 2023) and the deployment of the technology is adequately regulated and supervised

(Dziatkovskii, 2023). The development of appropriate regulations is considered the most important enabling factor that can accompany and support digital innovation, entrepreneurship and sustainable economic development. Regulations in particular must foster open and inclusive forms of trade by reducing barriers, facilitating cross-border digital transactions and supporting international collaboration. Policy bodies must also bring forward support initiatives such as subsidies, tax incentives for energy efficiency and the reduction of environmental impact. The digital infrastructure that provides administrative services to citizens also needs to be strengthened (Kwilinski et al., 2023). In order to have positive effects both economically and environmentally, the introduction of new ICTs must always be accompanied by educational campaigns and training of the personnel involved in its introduction (Farahani et al., 2022). The so-called *green open innovation*, i.e. a knowledge management system focused on supply chain relationships and business networks conveyed by digitalization, is proving to be a winning strategy for business development (Zhao et al., 2022). More generally, a new demoethical model must be developed that involves all the main stakeholders interested in digitainability. A new sensitivity towards sustainable development must be spread and strengthened, centerd on ethical principles and values aligned with it. Policymakers must ensure effective governance and leadership. The city and all the communities, organizations and institutions it encompasses must collaborate in making organic decisions that allow them to effectively achieve the Sustainable Development Goals following the paradigm of Society 5.0 and Industry 5.0 (Zanbayev et al., 2023; Aristovnik et al., 2021). In the well-being sector, digitalization not only has indirect effects, for example by lowering environmental pollution and increasing the quality of life in general with the re-engineering of production processes but can also have a direct impact in this area by creating services that can support prevention campaigns or improving the network of emergency services (Zhao et al., 2023; Liu et al., 2022). Digitalization can also be used to improve working conditions, using flexible forms of employment, work-life balance, employee decision-making, and personalized management of employee training. These solutions make it possible to improve the management of talent in organizations, promoting their retention (Lin and Wang, 2022). By resorting to the digital economy, the economic gap between territorial areas can be reduced, enabling a spillover effect on the territory linked to the occurrence of positive externalities and the production of innovative transmissible knowledge useful for achieving sustainable development (Ding et al., 2022). Finally, the new ICTs also make it possible to increase the degree of citizen empowerment, allowing them to reach increasingly higher levels of interaction and to be more involved in the development of territorial policies and initiatives (De Siqueira et al., 2022).

1.3.1 *Digitainability monitoring tools*

Various methodologies are used to monitor the level of digitainability achieved by a community, all based on subjective criteria and the active involvement of all actors involved in the sustainable development process.

The most widespread is that of the Digitainability Assessment Framework (DAF) which assesses the impact of digitalization in achieving the SDGs based on contextual information (Gupta et al., 2023; Gupta and Rhyner, 2022). DAF is a sort of evolution of the Theory of Change methodology (Rogers 2014; Valters 2014; Stein and Valters 2012. Vogel 2012), and analyses the impact of digitalisation from a technological, social, ethical and environmental point of view. As such, it is a useful tool available to political bodies that allows them to have a 360-degree overview of the level of digitainability achieved by a community. The DAF also makes it possible to effectively implement all the digitainability practices identified by the stakeholders involved in the study on the territory.

Experts are initially asked to draw up a list of viable digitisation interventions (DI). These include home automation, blockchain, AI, big data analytics and the Internet of Things (IoT) technologies. Once the DIs have been identified, the next step is to analyze all the possible effects of achievable digitainability. Another tool previously used was the Digitalization-Sustainability Matrix (DSM) (Gupta et al. 2020). Also in this case, the approach is participatory and involves the involvement of all stakeholders involved in the sustainable development process.

Through a six-month Thinkathon based on the Partecipatory Action Research (PAR) method (Chevalier and Buckles, 2013), contributions from all participants are collected, facilitating action-oriented dialogue, pragmatism and transdisciplinarity. In fact, the PAR method makes it possible to describe the problems faced by the participants in the Thinkaton, the action-oriented research strategies adopted by them and the resulting effects on the achievement of the SDGs.

Chapter 2

METHODOLOGY OF ANALYSIS

After a literature search on the factors related to the correct application of digitalization in the organizational field and on the dimensions of sustainable growth most sensitive to the introduction of digitalization, all the indicators identified by ISTAT will be examined to assess the level of achievement of the SDGs by our country, and those most correlated with digitization processes will be selected. A technique will then be used to draw up a sort of partial ranking of the level of sustainable development achieved with the digitization processes in relation to all the Italian provinces.

Studies similar to the one described in this thesis have already been carried out in the literature, all with the aim of assessing the effects of digitalization on the sustainable well-being (Zola, 2023).

The paper titled "Digitalization and contextual factors in Emilia-Romagna municipalities: A cluster and poset based approach" a explores the relationship between digitalization and the development of complementary factors across municipalities in the Emilia-Romagna region.

The document analyzes digitalization and contextual factors in Emilia-Romagna municipalities using a cluster and poset-based approach. It identifies areas where digitalization is closely linked to the development of complementary factors, such as human capital and institutional infrastructure. Through hierarchical cluster analysis and poset methodology, municipalities are ranked to better understand regional differences.

Baldazzi et al. (2019) compares PoSet and PLS-PM methodologies for assessing territorial well-being inequalities in Italy. Using Istat's multidimensional well-being indicators, the project aims to synthesize well-being levels while preserving local specificities.

The paper discusses the use of partially ordered set theory (PoSet) to analyse spatial inequalities in well-being. The PoSet methodology has been used to identify groups of regions or provinces with similar well-being profiles, avoiding determining a complete ordering based on a single score.

Ranking is a common goal in statistical evaluation studies, especially in socio-economics, typically based on multi-indicator systems (MIS).

However, when the indicators are ordinal and cannot be aggregated, traditional methods fail.

The aim of this thesis is a ranking of Italian provinces according to their level of digitalization using partial order theory (PoSets).

In the following chapter of this thesis the procedure employs tools from Partial Order Theory and computes the final synthetic scores of the 106 Italian provinces, without the compensation effects of classical composite indicators.

Arcagni, Cavalli e Fattore (2021): *"Instead of collapsing the elementary indicators into final figures, trying to measure sustainability against an absolute scale that does not actually exist, the synthetic scores are here computed by building a global system of comparisons among the multidimensional sustainability profiles of the cities and by quantifying their relative "dominance degrees", given the evaluation context provided by the input indicator system"* (page 2).

Partially ordered sets are just regular sets in which certain pairs of elements can be compared and ordered meanwhile other pairs of elements remain incomparable.

Incomparability among elements isn't just due to insufficient information but reflects fundamentally different aspects of the trait, offering a more nuanced understanding. This complexity, especially in conflicting dimensions like city sustainability, underscores the value of partially ordered sets in multi-indicator systems.

2.1 *PoSet Analysis Methodology*

In the following paragraphs, the Italian provinces denoted by $C=\{x_1,...,x_{106}\}$ are analyzed. Each province is evaluated in a space I={a_1,...,a_k}, characterized by a set of attributes that can be associated with it.

Table I includes the BEST and SDGs indices that represent the dimensions of digitalization.

The expression $a_i(x)$ indicates the row of all the indices associated with the province x.

For the provinces thus described, the following sorting axioms apply:

Reflexivity: $x \leq x$, i.e. each province can be compared to itself;

Anti-symmetry: if $x \leq y$ and $y \leq x$ happens, it is inferred that $x = y$;

Transitivity: If $x \leq y$ and $y \leq z$ happens, it is automatic that $x \leq z$.

Following the theory of partially sortable sets or *posets* (Bruggemann et al., 2021; Bruggemann and Annoni, 2014; Bruggemann et al. 2014; Bruggemann and Carlsen, 2011; Bruggemann and Patil, 2011; Bruggemann and Halfon, 1999; Bruggemann et al. 2004) a province x is considered better, i.e. higher, than a province y if ai(x)>=ai(y) for at least one indicator.

If, on the other hand, for each indicator we have $a_i(x)=a_i(y)$, then the common x and y are considered equivalent, i.e. belonging to the same rank.

Whenever $x \leq y$ or $y \leq x$, the two provinces are comparable, that is, an order relationship can be established between the two.

If this does not happen, then the two provinces are incomparable (x||y).

Following the definitions of Fattore et al. (2012), the first case constitutes an example of a *partial order chain* P, while the second case is an example of an *anti-chain*. All chains have a *length* equal to the number of elements that can be placed on them. The number of elements in the longest chain is the *height* of the poset, while the maximum number of elements in the anti-chain is the *width* of the poset.

When it happens that all the elements of the set under analysis turn out to be comparable, we are faced with a special case of poset, that of a *completely sortable* set.

The incomparables between the elements can be analyzed through the creation of an anticatene matrix.

In general, the indicators that generate most of the incomparables are those that have the greatest impact on the phenomenon analyzed, since their introduction or elimination upsets the system of provinces.

Chains and antichains are represented using the *Hasse diagram*. Within this diagram, if the element representing one province turns out to be connected to another element associated with another province, then the two provinces are comparable, otherwise they are incomparable. For the transitivity property, all provinces in a chain are comparable.

As can be guessed, the analysis of phenomena through the theory of posets allows us to arrive at an ordering of the elements of the studied set without resorting to aggregative methods for the calculation of the rank that are based on a series of arbitrarily chosen weights.

With the theory of posets, however, it is only possible to establish ordering relationships between elements, but it is not possible to assign a ranking score to each element.

To be able to do this, Bruggemann et al. (2021) defined a ranking score linked to local partial ordering models (LPOM), a sort of average calculated by considering, for each element, the number of elements belonging to the following subsets:

- **Subset of inferiority** (Down Set) D(x) = {y ∈ P: $y \leq x$}
- **Subset of Superiority** (Up Set) U(x) = {y ∈ P: $y \geq x$}
- **Subset of incomparability** (Incomparable) I(x) = {y ∈ P: y$\|x$}

The LPOM formula for calculating the final ranking score r(x) of item x becomes as follows:

$$r(x) = d(x)\frac{n+1}{n+1-i(x)}$$

Where d(x) is the number of elements y for which y is $\leq x$, i(x) is the number of elements y for which $y \parallel x$ and n is the total number of elements in the POSET.

The concept of ranking extraction discussed by Fattore and Arcagni (2018) involves using mutual ranking probabilities to address challenges in dimensionality reduction and ranking within multidimensional systems of ordinal variables. This approach primarily focuses on systems where ordinal variables interact, meaning that data points are organized not as absolute values but in relation to each other, representing rankings or orderings.

The authors propose a methodology that utilizes mutual ranking probability matrices, which capture partial order relations between the variables. These matrices help in approximating rankings, allowing for an effective dimensionality reduction. In simple terms, instead of using the raw ordinal data (which may be complex or multidimensional), the system approximates how items rank relative to one another based on the probabilities derived from the relationships between variables.

The matrix representations of a “Finite Poset” as were defined, once again, by Arcagni, Cavalli e Fattore (2021):

The Matrix of Mutual Ranking Probabilities (MRP) captures the likelihood that one element x_j is ranked higher than another element x_i across all linear extensions of the poset π. Specifically, the entry M_{ij} represents the fraction of linear extensions λ where x_j is ranked above x_i, which is calculated as:

$$M_{ij} = \frac{|\{\lambda \in \Omega(\pi) : x_i \leq_{\lambda} x_j\}|}{|\Omega(\pi)|} \quad (i, j = 1, \dots, |X|)$$

By construction, the diagonal of M is composed of 1s and Mij ¸ $Mji = 1$ $(i \neq j)$.

M_{ij} represents the element of the MRP matrix that gives the probability that the element x_j is ranked above x_i in any linear extension of the poset.

$\Omega(\pi)$ is the set of all possible linear extensions of the poset π and λ represents a linear extension of the poset. A linear extension is a way of arranging all the elements of a poset in a linear, or total, order.

The numerator counts how many times, out of all possible linear extensions, x_j is ranked above x_i.

The denominator is the total number of linear extensions of the poset, basically the number of ways the elements of the poset can be ordered linearly.

Finite posets can be represented using three types of matrices:

Incidence Matrix (Z): The matrix Z has entries $Z_{ij} = 1$ if $x_i \leq x_j$ and $Z_{ij} = 0$, otherwise.

Cover Matrix (C): The binary matrix C has entries $C_{ij} = 1$ if $x_i < x_j$ and $C_{ij} = 0$, otherwise. Transitivity $\leq$ is determined by the associated cover relation <.

Matrix of Mutual Ranking Probabilities (M): The matrix M has entries M_{ij} representing the fraction of linear extensions where x_j is ranked higher than x_i. It is constructed by evaluating all linear extensions of the poset.

Relations between Matrices

Cover and Incidence Matrix: the incidence matrix Z can be obtained from the cover matrix C using the formula $Z = Bin(C^{|X|-1})$ where $Bin\ (\cdot)$ sets to 1 all of the non-null entries of its argument.

Matrix C can be obtained from incidence matrix Z by $C = H - Bin(H^2)$, where H is obtained from Z by setting the diagonal elements to 0.

There isn't a direct formula from the Z (incidence matrix) and M (matrix of mutual ranking probabilities), but starting from the incidence matrix, the computation of all the linear extensions of the input poset leads to the obtainment of the matrix of mutual ranking probabilities by direct enumeration. Z can be obtained from M by setting $Z_{ij} = 1$ wherever $M_{ij} = 1$.

The Cover matrix C and the matrix M can be linked through the Incidence matric Z.

2.1.2 *PoSet: literature overview*

This choice to resort to the theory of posets to study the phenomenon of digitainability goes against the trend with respect to the study methods used to address multidimensional evaluation problems in the socio-economic field (such as in the study of social well-being and sustainable well-being). In these cases, a composite ranking index is always calculated, consisting of a weighted average of indicators selected by a group of experts together with their weights. Just to give an example, the same Quality of Life indicator updated annually by

LAB24, the statistical laboratory of Il Sole 24 Ore, to draw up the ranking of all Italian regional capitals based on the level of social well-being achieved is based on a composite ranking index calculated through a weighted average of the values of indicators judged suitable to represent the social well-being of 3 specific targets of the Italian population (children from 0 to 10 years, young people from 18 to 35 years, seniors over 65).

However, the dimensions of well-being, as also emerged from the present study, are most often scarcely interdependent (Alaimo and Maggino, 2020). This raises many doubts about the validity of well-being studies resulting from a one-dimensional reduction of the problem, since the calculation of composite ranking indices seems to be based on subjective, arbitrary and potentially misleading pragmatic choices (Smirlis, 2020; Ruiz et al., 2020, Aparicio and Kapelko, 2019; Albo et al., 2019; Fattore, 2013). In the case of well-being-related assessments, the aggregation of indices as a method of summarizing information is further complicated by the presence of ordinal variables[1]. To approach the problem, scaling techniques are used, which consist in supposing "the existence of latent continuous scales underlying the ordinal manifestation

[1] Ordinal variables consist of three or more modes that have a predefined order. For example, the highest educational qualification obtained by a person is an ordinal qualitative variable because there is a logical ordering between the modalities: elementary or middle school, high school diploma, degree, qualification higher than a degree. On the other hand, it cannot be considered a quantitative variable as the difference, for example, between diploma and degree is not the same as between degree and qualification higher than a degree. In other words, the difference between these modes cannot be considered constant.

of the data" (Fattore, 2017; Fattore, 2013). However, it has been demonstrated in the literature (Madden, 2010) that transforming the initial ordinal scores into numerical scores by resorting to scaling techniques can even obtain discordant results.

PoSets are therefore the only analysis tools in the study of well-being that can represent the data of interest in an appropriate way.

Studies similar to the one described in this thesis have already been carried out in the literature, all with the aim of evaluating the effects of digitalization on various dimensions of sustainable well-being (Zola, 2023).

What distinguishes the present study from others conducted on digitainability through the Posets technique is the study carried out on the dimensions of sustainable development that can be influenced by the digitization process carried out with the Prisma methodology and above all the attempt to establish a methodology that can be carried out for any provincial capital municipality present on the Italian territory. For this reason, only open data sets of national indicators made available by ISTAT have been taken into consideration. The ultimate goal is to arrive at the definition of national and regional rankings that are more reliable than those based on composite ranking indices such as the one often cited made available by LAB24. The digitainability rankings defined with this methodology can provide useful guidance on how to improve the digitization approach adopted by the provinces to more effectively achieve the sustainable development goals defined by the UN 2030 Agenda.

2.2 *Cluster*

2.2.1 *A brief review of cluster analysis*

In scientific research, two main clustering techniques are adopted, the partitional and the hierarchical (Everitt et al., 2011).

The hierarchical clustering analysis returns a branched diagram called a dendogram, which effectively represents the similarity relationships between the provinces, based on the values of the chosen indicators. Cluster analysis is the process of partitioning a set of data objects (observations) into subsets. The set of clusters resulting from a cluster analysis can be reffered to as clustering.

Hierarchical clustering techniques proceed by either a series of succesive mergers or a series of successive divisions.

The cluster algorithm is an agglomerative hierarchical method that starts with the individual objects. The most similar onjects are first grouped, successively it merges the objects or groups close to one another, until all the groups are merged into 1. However, hierarchical methods suffor from the fact that once a step (merge or split) is done, it cannot be undone.

The different clustering techniques can be divided into 5 methods: Single, complete, average, centroid and Ward's.

In literature various papers were based on this statistical techniques, such as Mehmet Çağlar1 and Cem Gürler, they used cluster analysis to rank 110 countries based on their progress towards the Sustainable Development Goals (SDGs).

Using the K-means method, the countries were divided into 5 clusters. Each cluster was analyzed according to the socio-economic (GDP per capita, human capital) and political-cultural (governance, institutions, human freedom) structure of the member countries. The analysis revealed that clusters with better socioeconomic and political-cultural structures tend to have superior progress on the SDGs.

Chapter 3

A CASE STUDY

3.1 *Introduction*

Italy was the first country to include a system of Equitable and Sustainable Wellbeing (BES) indicators in the budget cycle (law 163/2016), as an economic-financial planning tool aimed at measuring the results of public policies as part of the path traced by the 2030 Agenda. The indicators were defined by a Committee for Equitable and Sustainable Wellbeing Indicators, established at ISTAT by Presidential Decree of 11 November 2016, chaired by the Minister of Economy and Finance or his delegated representative and composed of the President of ISTAT, the Governor of the Bank of Italy or their delegated representatives and two experts in the field from universities and research institutions. The results of this activity led to the identification of twelve BES indicators listed below:

1. Adjusted average disposable income per capita. Ratio between the adjusted gross disposable income of households (consumers + producers) (i.e. inclusive of the value of in-kind services provided by public and non-profit institutions), and the total number of people residing in Italy;

2. Disposable Income Inequality Index. Ratio of the total equivalised income received by the top 20% of the population to that received by the bottom 20% of the population;

3. Absolute poverty index. Percentage of people belonging to households with a total consumption expenditure below the absolute poverty threshold value, out of the total number of residents;

4. Healthy life expectancy at birth. The average number of years that a child born in the reference year can expect to live in good health, assuming that the risks of illness and death at different ages observed in that year remain constant over time;

5. Excess weight. Standardised proportion of overweight or obese people aged 18 and over to the total number of people aged 18 and over;

6. Early exit from the education and training system. Percentage of the population aged 18-24 with at most a lower secondary school diploma (middle school diploma), who do not have regional professional qualifications obtained in courses lasting at least 2 years and do not attend education courses or other training activities;

7. Rate of non-participation in work, with relative breakdown by gender. Ratio between the sum of "available" unemployed and inactive (people who have not looked for work in the last 4 weeks but are available to work), and the sum of the labour force (set of employed and unemployed) and "available" inactives, referring to the population between 15 and 74 years old;

8. Ratio between the employment rate of women aged 25-49 with pre-school children and women without children. Ratio of the employment rate of women aged 25-49 with at least one child of pre-school age (0-5 years) to the employment rate of women aged 25-49 without children, per 100;

9. Predatory Crime Index. Number of victims of home burglaries, pickpocketing and robberies per 1,000 inhabitants;

10. Civil Justice Efficiency Index. Average effective duration in days of ordinary civil proceedings defined by the courts;

11. Emissions of C02 and other climate-altering gases. Tonnes of CO2 equivalent emitted on an annual basis by agricultural, urban and industrial activities, per inhabitant;

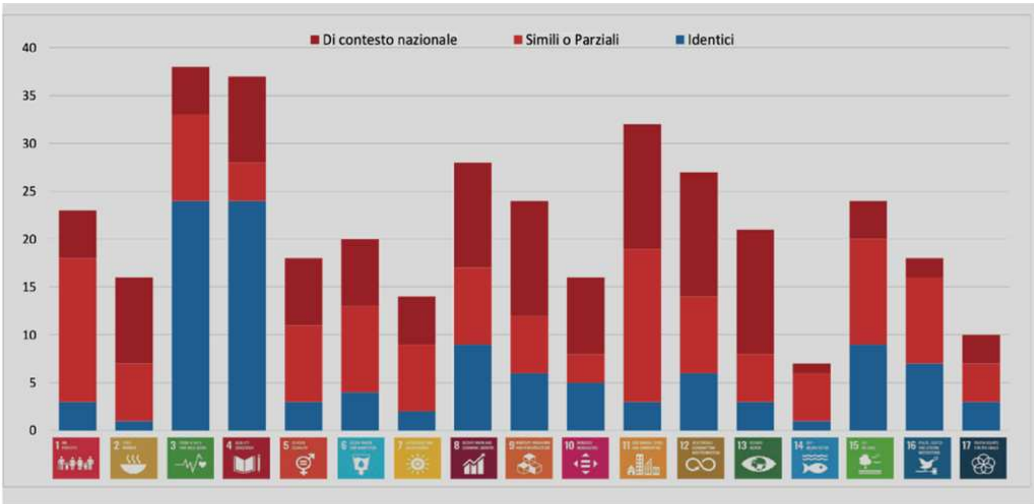
12. Index of illegal building. Number of illegal constructions per 100 constructions authorized by the provinces;

On the basis of ISTAT's analysis of these indices, the Ministry of Economy and Finance draws up two documents. A special annex to the DEF that is updated every three years, reporting the trend of these indicators over the last three years (as well as the forecasts on their evolution), and an annual report that is presented to the Chambers by 15 February on the evolution of the trend of the

BES indicators, based on the effects determined by the budget law for the current three-year period.

As can be seen, the BES indicators do not fully cover all the provisions related to the 17 SDGs. It is also found that more than half of the SDGs (2, 5, 6, 7, 9, 12, 14, 15, 17) fail to be monitored by these measures.

Figure 8: Istat-SDGs statistical measures, by type



Source: Report SDGs 2024 (page 8)

Another tool for monitoring the progress made by Italy in achieving the SDGs is provided by ISTAT, which since 2016 has published a system of indicators for monitoring each of the SDGs on a dedicated information platform. The measures related to the SDGs updated annually by ISTAT are also used to monitor the progress achieved in the implementation of the Italian PNRR, where the SDG indices are traced back to each of the 6 missions envisaged by the PNRR. The SDG indicator framework has been refined over the years, from 95 national measures for 66 UN-IAEG indicators released in December 2016, to the current version that identifies 372 statistical measures for 139 indicators (Figure 8).

Figure 9: Comparison between BES and SDG indicator

BES		SDGs	
1. Salute	4 indicatori	4 nel Goal 3	
2. Istruzione e formazione	8 indicatori	7 nel Goal 4 1 nel Goal 8	
3. Lavoro e conciliazione tempi di vita	10 indicatori	2 nel Goal 5 8 nel Goal 8	
4. Benessere economico (a)	5 indicatori	3 nel Goal 1 3 nel Goal 10	
5. Relazioni sociali			
6. Politica e istituzioni (a)	8 indicatori	4 nel Goal 5 5 nel Goal 16	
7. Sicurezza	3 indicatori	1 nel Goal 5 2 nel Goal 16	
8. Benessere soggettivo			
9. Paesaggio e patrimonio culturale	2 indicatori	1 nel Goal 11 1 nel Goal 13	
10. Ambiente (b)	11 indicatori	1 nel Goal 1 2 nel Goal 6 1 nel Goal 7 1 nel Goal 8 3 nel Goal 11 2 nel Goal 12 2 nel Goal 13 1 nel Goal 14 2 nel Goal 15	
11. Innovazione, ricerca e creatività	3 indicatori	3 nel Goal 9	
12. Qualità dei servizi (a)	8 indicatori	1 nel Goal 1 3 nel Goal 3 1 nel Goal 6 1 nel Goal 9 2 nel Goal 11 1 nel Goal 16	

Source: Report SDGs 2022 (page 9)

The ISTAT SDG indicators have numerous points of contact with the BES system of indicators, especially with the 62 indicators used in the Economic and Financial Document (DEF) as shown in figure 9.

Finally, Figure 10 disaggregates the latest measures identified by ISTAT related to the achievement of the SDGs according to the type of province, region, province, gender, age group, educational qualification, citizenship/nationality and the presence of disability.

Figure 10: ISTAT measures related to the achievement of the disaggregated

Variabile di classificazione	Misure statistiche Istat-SDGs	Goal
Grado di urbanizzazione / Comune capoluogo / Tipologia comunale	76	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17
Regione	209	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
Provincia	17	1, 3, 4, 6, 7, 8, 9, 11, 12, 15, 17
Genere	125	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 13, 16, 17
Classe di età	78	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 13, 16, 17
Titolo di studio	25	1, 3, 4, 5, 8, 9, 11, 17
Cittadinanza / Nazionalità	58	1, 3, 4, 5, 7, 8, 9, 10, 11, 16
Presenza di disabilità	18	1, 3, 4, 10

SDGs

Source: Report SDGs 2024 (page 9)

Starting from the BES indicators for the Territories (BEST) and the SDG indicators developed by ISTAT available, also on the basis of the scientific evidence collected, in the next chapter the measures related to the phenomenon studied in this thesis will be selected, i.e. the effects of digitalization on provincial sustainable development.

3.2 Dataset: insights and reference year

The dataset chosen for the analysis, that will be carried out in the following chapter, was created based on the indices provided by ISTAT, in particular from the BES for territories and SDG dataset.

The indices were downloaded from the ufficial site on the 16th of June 2024 (BEST published on the site on the 16th of June 2023, SDG on the 20th of December 2023).

The indices that were chosen to describe the digitalization index are listed in the Table 1.

Each of the iware labeled with the capital letters that symbolize the index itself for convinience, 6 of the listed indices were taken from th BEST database and the data is provincial, meanwhile the last 3 from the SDG and the data is regional.

The data that was gathered for this research is mainly provincial, however as stated before, 3 out of 9 indices are regional. To incorporate consistently the regional and provincial dataset, we assume that provinces perform as their region.

Table I – indices that define the digitalization inde.

LABEL	DESCRIPTION	UNIT	SOURCE	YEAR	LEVEL
ALP	Adequate literacy proficiency (students in grades III, lower secondary school)	%	ISTAT - BEST	2022	P
ANC	Adequate numerical proficiency (students in grades III, lower secondary school)	%	ISTAT - BEST	2022	P
FNC	Fixed network coverage of ultra-fast internet access	%	ISTAT - BEST	2022	P
CGT	College graduates and other tertiary degrees (25-39 years old)	%	ISTAT - BEST	2022	P
PCE	Participation in continuing education	%	ISTAT - BEST	2022	P
HSD	People with at least a high school diploma (25-64 years old)	%	ISTAT - BEST	2022	P
BDS	Youth and adults with information and communication (ICT) skills, by type of skill - Digital skills at least basic	%	ISTAT - SDG	2021	R
SDY	People with a tertiary STEM degree in a year (20-29 years old)	Per 1000 residents	ISTAT - SDG	2020	R
IU	People aged 16-74 years who have used the internet in the past 3 months at least once a week (including every day)	%	ISTAT - SDG	2022	R

Source: own elaboration – P=Provincial Level; R=Regional Level

Thus, it was assumed that the values of the regional indices are constant and uniform across the provinces of the given region.

The earliest data that was available and reliable goes back to 2022, however BDS is from 2021 and SDY is from 2020.

The dataset consists of the Italian provinces, but not all data were available, in fact the data present were for 106 provinces instead of 110. in fact, the missing provinces are those of Sardinia, specifically: Carbonia-Iglesias, Medio Campidano e Olbia-Tempio.

For the remaining provinces the dataset doesn't have any missing data.

3.2.1 Descriptive statistics

The ALP index's minimun value corresponds to 30,6 (Trento, Trentino-Alto Adige) and maximum to 73,1 (Belluno, Veneto).

The ANC index's minimun value corresponds to 30,5 (Crotone, Calabria) and maximum to 74,5 (Sondrio, Lombardia).

The FNC index's minimun value corresponds to 15,4 (Nuoro, Sardegna) and maximum to 86,6 (Prato, Toscana).

The CGT index's minimun value corresponds to 13,2 (Taranto, Puglia) and maximum to 42,3 (Bologna, Emilia-Romagna).

The PCE index's minimun value corresponds to 3,5 (Imperia, Liguria) and maximum to 22 (Cagliari, Sardegna).

The HSD index's minimun value corresponds to 45,6 (Caltanissetta, Sicilia) and maximum to 75,2 (Roma, Lazio).

The BDS index's minimun value corresponds to 33,8 (Catanzaro, Cosenza, Crotone, Reggio Calabria, Vibo Valentia - Calabria) and maximum to 52,9 (Frosinone, Latina, Roma, Viterbo – Lazio).

The SDY index's minimun value corresponds to 3,1 (Emilia-Romagna) and maximum to 21,5 (Agrigento, Caltanissetta, Catania, Enna, Messina, Palermo, Ragusa, Siracusa, Trapani – Sicilia).

The IU index's minimun value corresponds to 70,8 (Perugia, Terni - Umbria) and maximum to 88,3 (Catanzaro, Cosenza, Crotone, Reggio Calabria, Vibo Valentia – Calabria; Gorizia, Pordenone, Trieste, Udine - Friuli-Venezia Giulia; Genova, Imperia, Savona, La Spezia - Liguria).

Table II – descriptive statistics for each of the indices.

	ALP	ANC	FNC	CGT	PCE	HDS	BDS	SDY	IU
Average	61,05	55,92	47,06	27,18	9,38	61,91	45,66	15,2	84,12
Standard error	0,75	1,04	1,48	0,59	0,3	0,72	0,66	0,45	0,38
Median	62,8	58,5	44,7	26,2	8,8	62,45	49,1	16,4	85,4
Mode	65	61,9	63,2	28,6	8,8	67,8	51	15,9	88,3
Standard deviation	7,72	10,73	15,19	6,07	3,1	7,41	6,77	4,65	3,89
Kurtosis	1,4	-0,64	-0,23	-0,39	2,54	-0,69	-0,97	1,68	1,01
Asymmetry	-1,11	-0,62	0,35	0,31	1,11	-0,29	-0,83	-1,38	-1,16
Minimum	30,6	30,5	15,4	13,2	3,5	45,6	33,8	3,1	70,8
Maximum	73,1	74,5	86,6	42,3	22	75,2	52,9	21,5	88,3

Source: own elaboration

Although in 2022 in Italy the share of the population between 30 and 40 years old who completed university studies decreased compared to the previous year (well below the European target of 40%) and the incidence of graduates in

STEM disciplines (science, technology, engineering and mathematics) is very low (only 1, 6% of all individuals aged 20-29), the presence of graduates is strongly correlated with the phenomenon of digitalization (ISTAT, 2023).

Table II reports summary statistics for all the indices.

Continuing education is also strongly correlated with the phenomenon of digitalization. During 2021, 9.9% of individuals aged between 25 and 64 carried out at least one training activity in the 4 weeks prior to the interview.

The phenomenon signals a recovery compared to the loss of training that occurred in 2020 due to the reduction in mobility and the closure of places of learning.

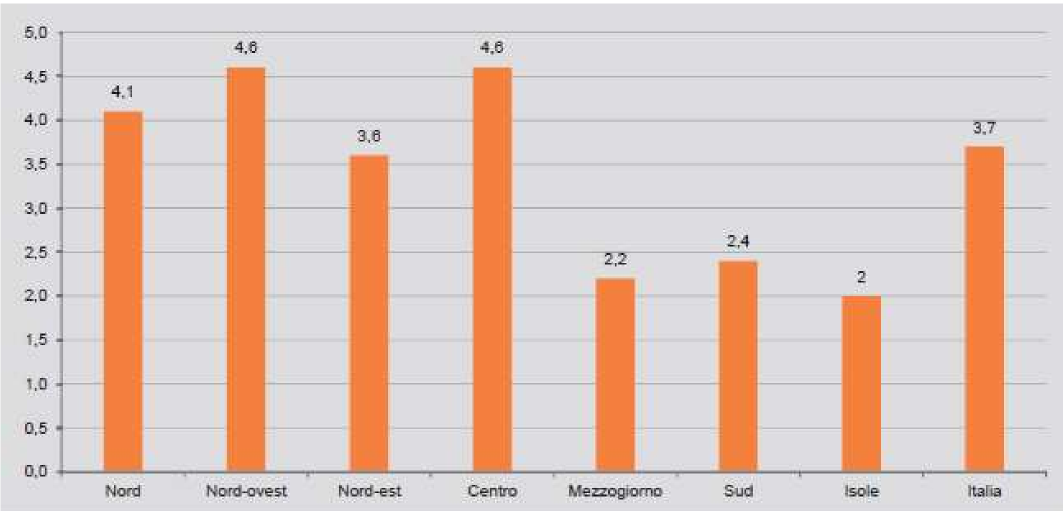
Figure 11 – Participation in continuing education, by geographical distribution

Source: SDG Report 2022 (page 64)

The presence of graduates in organizations and the intensification of continuing education activities may also have had a positive impact on the skills possessed by the percentage of employees in specialized ICT positions, which in 2021 remained stable compared to the previous year with a value of 3.7%.

The percentage of employees in ICT positions is particularly high in center and north-west Italy, as can be seen from Figure 12.

Figure 12– Employees with ICT positions by geographical distribution.



Source: SDG Report 2022 (page 110)

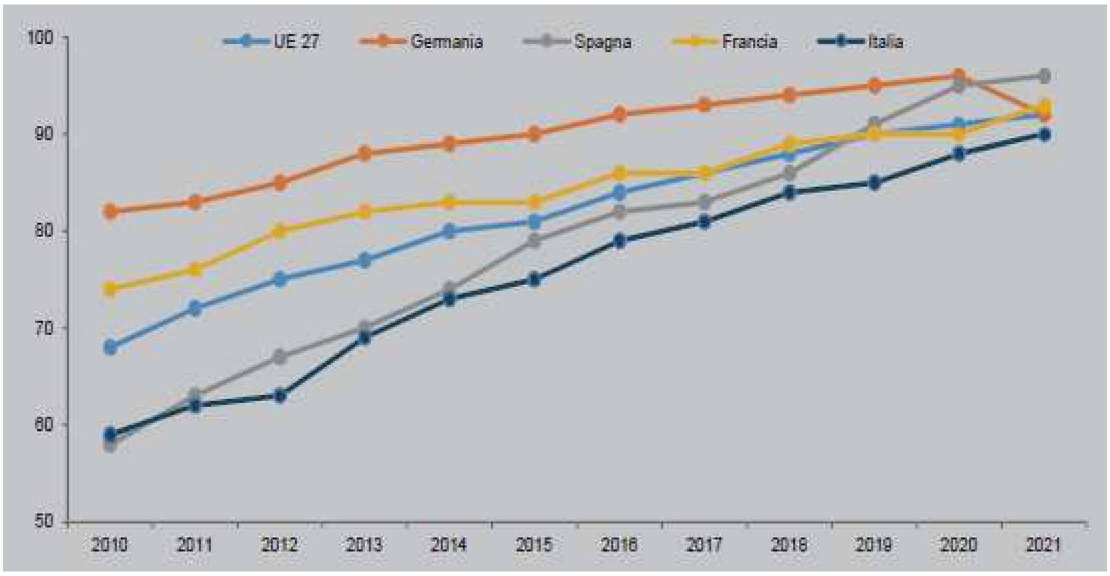
As far as internet access for Italian households is concerned, the COVID-19 pandemic seems to have accelerated the use of digital technologies in different areas of daily life, demonstrating the potential of ICT in the exercise of fundamental rights, such as those related to education. As can be seen in Figure

16, between 2019 and 2021, Italy almost managed to close the gap with the EU27 average, recording an increase of 5 percentage points

Unfortunately, the BEST and SDGS indices do not currently allow to verify, with regard to the dimension of digitalization, the development of human capital within organizations.

First of all, there is a lack of indicators that make it possible to quantify the level of computer literacy achieved by the local population and the use of flexible forms of work.

Figure 13 – Households with at least one member aged 16-74 who have access to the Internet.



Source: Tesi Magistrale "L'impatto delle connessioni in fibra ottica sul grado di capacità innovativa delle imprese italiane" – Politecnico di Torino. (page 18). https://webthesis.biblio.polito.it/secure/31131/1/tesi.pdf

The development of online and e-commerce services, the investment in new ICT technologies, the level of re-engineering of organizational processes and the degree of inter-organizational sharing of resources (personnel, services, data, information, knowledge, etc.) are not even tracked, all factors enabling digitainability.

3.3 Methodology of Analysis

3.3.1 Cluster analysis

A first phase of analysis was carried out with the aim of obtaining groups of homogeneous provinces on the basis of the profile of the values of the selected indicators.

It was decided to use the hierarchical clustering technique because the number of possible groupings is not known in advance, which is a crucial information to be able to use the first technique.

The method that has been chosen for the hierarchical clustering is the Ward method. This technique consists of grouping the various clusters identified as you proceed towards the upper part of the dendogram, trying to minimize the variance between the clusters. Ward's method, in addition to allowing an easily interpretable representation of groupings, is less susceptible to the presence of noisy data and outliers.

The other four types of clustering techniques were performed too, but due to outliers (average method) and not easily interpretable results (single, complete and centroid method) the Ward method was chosen as explained previously.

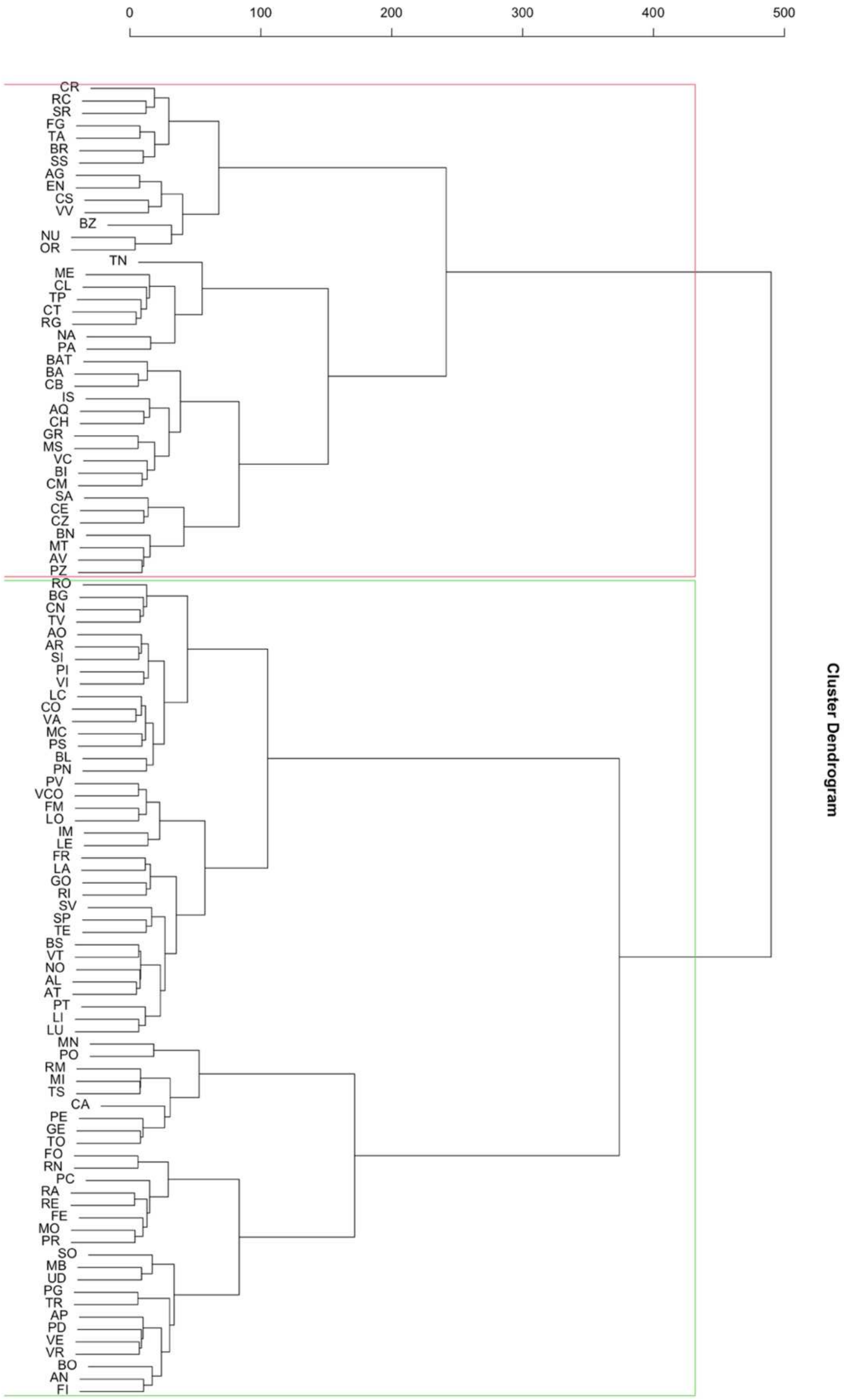


Figure 14: result of cluster analysis, 2 groups.

Source: own elaboration

Nevertheless, the dendograms of every clustering method will be listed in the appendix along with the R code used to plot them.

3.3.2 Silhouette and Sum of Squares method

Analysing the dendrogram reveals that at a height of 400, it divides into two large clusters. However, this level of division may be reductive and may not fully capture the intrinsic complexity of the data. Choosing this threshold might overlook significant subgroups within the data that are revealed at different heights.

Therefore, to determine the most appropriate number of clusters, I performed the Silhouette analysis, which measures how well an observation is clustered and it estimates the average distance between clusters. It measures the quality of clustering by determining how well each object lies within its cluster.

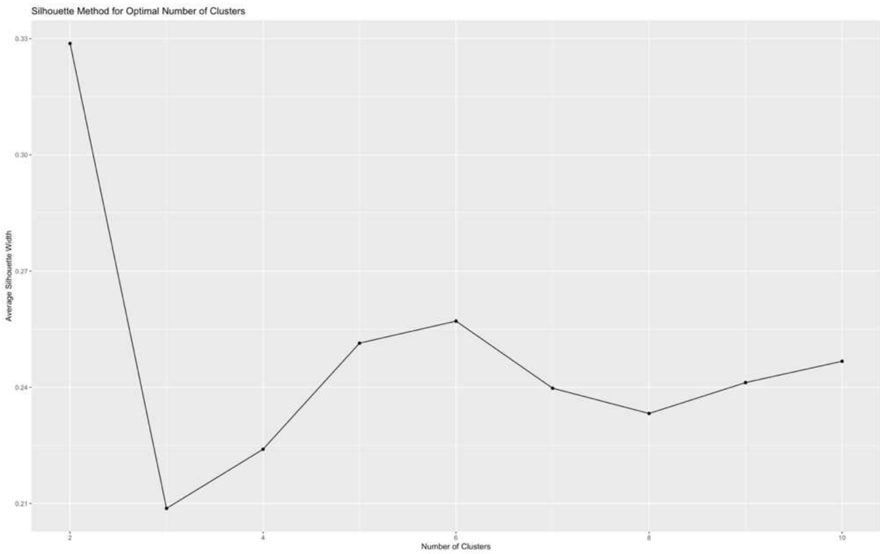
Figure 15: Average Silhouette Width

Clusters	Avg_Silhoutte
2	0.3287
3	0.2087
4	0.2240
5	0.2514
6	0.2570
7	0.2397
8	0.2332
9	0.2412
10	0.2467

Source: own elaboration.

Figure 15 displayes the average silhouette width, as discussed before, the second-best option will be chosen, in this case the best number of groups will be 6, as a large average silhouette implies that it’s well clustered.

Figure 16: Average Silhoutte method for optimal number of clusters.



Source: own elaboration.

Figure 16 displays the corresponding Silhouette. The horizontal axis report the number of clusters and on the vertical one the corresponding heights.

Moreover, the Sum of Squares method was performed which shows the optimal number of clusters by minimizing the within-cluster sum of squares (a measure how tight each cluster is) and maximizing the between-cluster sum of squares (a measure of how separated each cluster is from the others).

Figure 17 shows the within sum of squares.

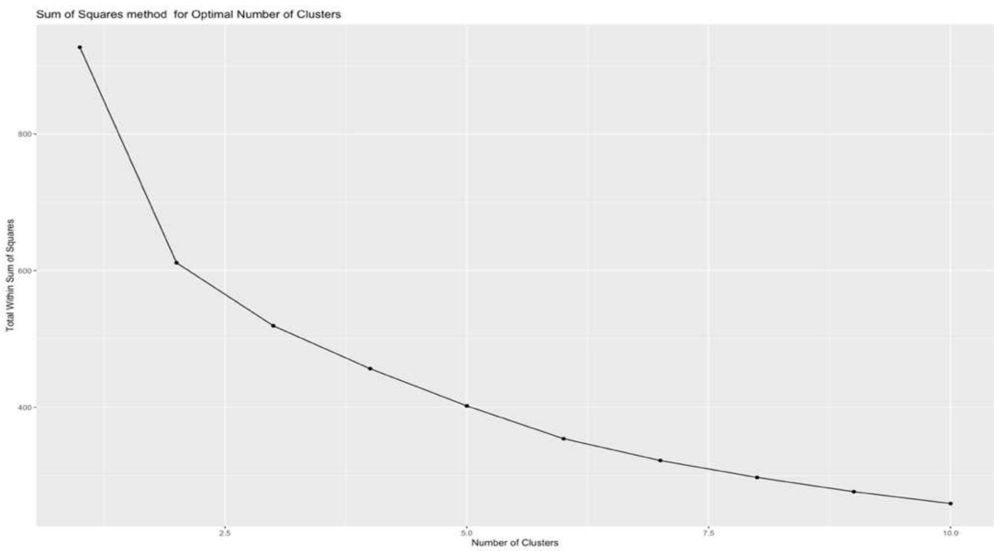
Figure 17: WSS

Clusters	WWS
1	927.0000
2	611.5095
3	519.3015
4	456.5648
5	402.00483
6	354.0612
7	322.0713
8	297.3214
9	276.4501
10	259.1326

Source: own elaboration

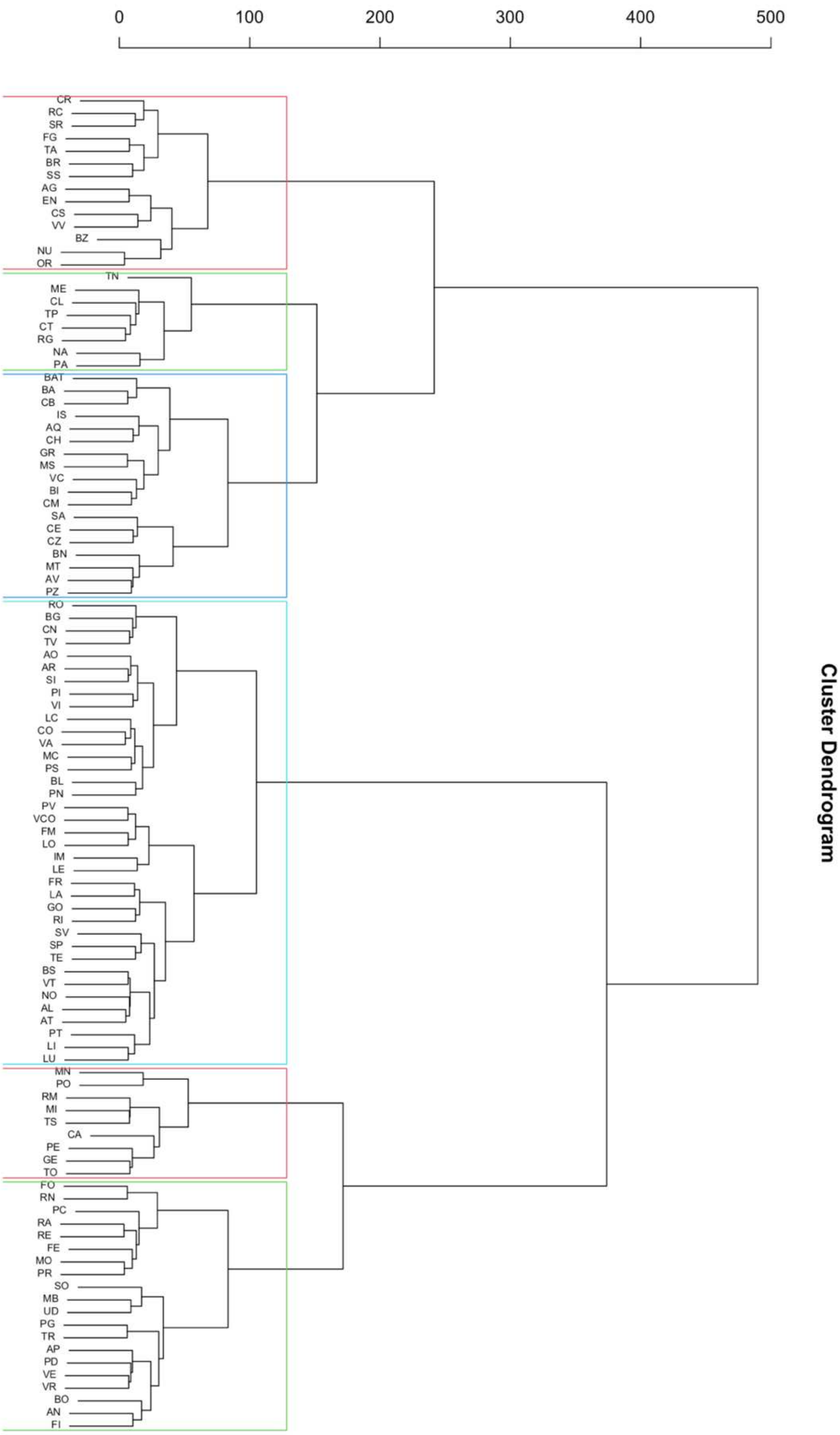
Figure 18 displays the corresponding WWS. The horizontal axis report the number of clusters and on the vertical one the corresponding heights.

Figure 18: Sum of Squares method for optimal number of clusters.



Source: own elaboration.

Figure 19: dendogram with Ward's method, subdivided into 6 groups.



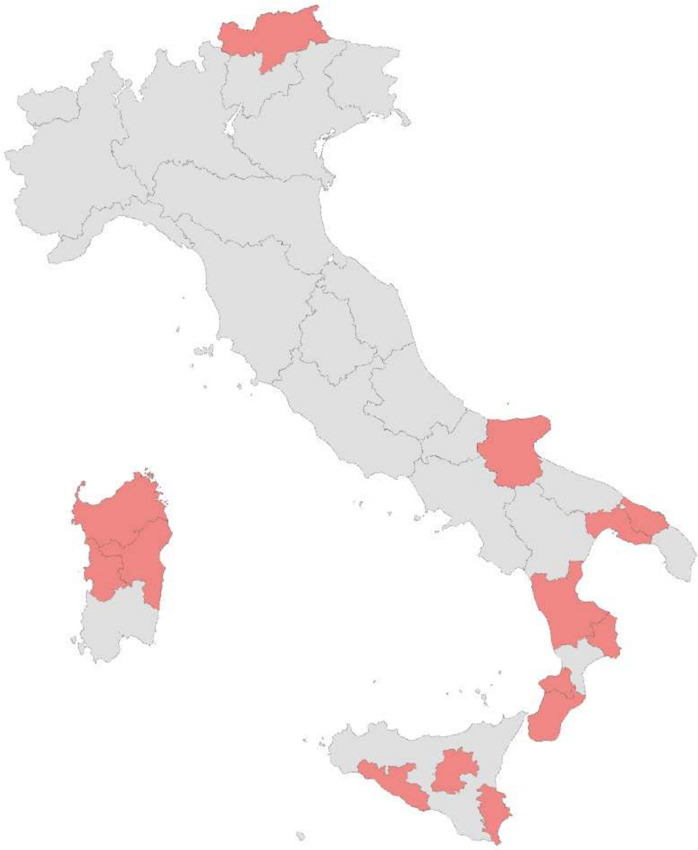
Source: own elaboration.

Hence, figure 19 reports the dendogram divided into 6 groups that have been highlighted with rectangles of different colors.

3.3.3 Definition and attribution of provinces to the belonging cluster

By analysing the dendrogram from top to bottom, the various provinces can be placed in the cluster in which they belong.

Figure 20: cluster I



Source: own elaboration

The provinces that belong to cluster I are the following: Crotone, Reggio Calabria, Siracusa, Foggia, Taranto, Brindisi, Sassari, Agrigento, Enna, Cosenza, Vibo Valentia, Bolzano, Nuoro, Oristano.

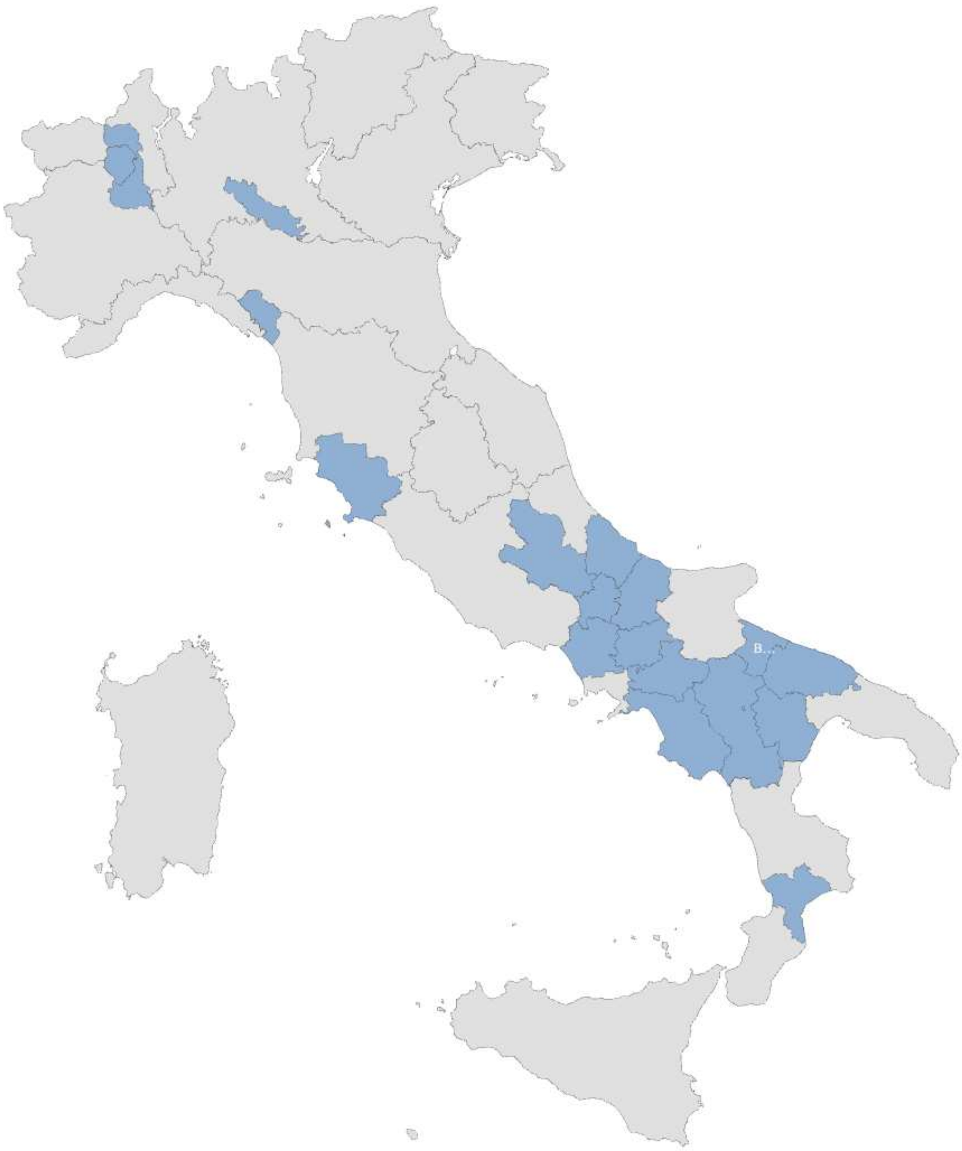
The provinces that belong to cluster II are the following: Trento, Messina, Caltanissetta, Trapani, Catania, Ragusa, Naples and Palermo.

Figure 21: cluster II

Source: own elaboration

The provinces that belong to cluster III are the following: Barletta-Andria-Trani, Bari, Campobasso, Isernia, L'Aquila, Chieti, Grosseto, Massa-Carrara, Vercelli, Biella, Cremona, Salerno, Caserta, Catanzaro, Benevento, Matera, Avellino, Potenza.

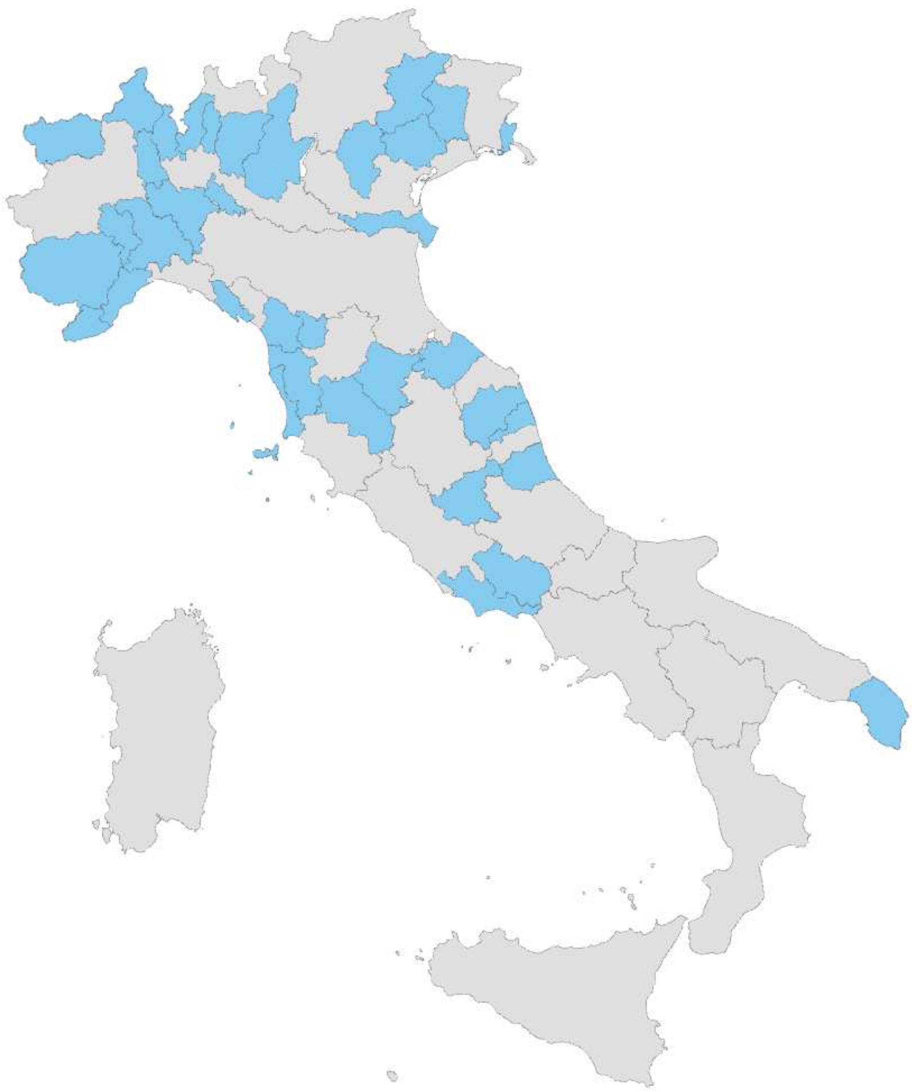
Figure 22: cluster III



Source: own elaboration

The provinces that belong to cluster IV are the following: Rovigo, Bergamo, Cuneo, Treviso, Aosta, Arezzo, Siena, Pisa, Vicenza, Lecco, Como, Varese, Macerata, Pesaro-Urbino, Pavia, Verbano-Cusio-Ossola, Fermo, Lodi, Imperia, Lecce, Frosinone, Latina, Gorizia, Rieti, Savona, La Spezia, Teramo, Brescia, Viterbo, Novara, Alessandria, Asti, Pistoia, Livorno and Lucca.

Figure 23: cluster IV



Source: own elaboration

The provinces that belong to cluster V are the following: Mantua, Prato, Rome, Milan, Trieste, Cagliari, Pescara, Genoa and Turin.

Figure 24: cluster V

Source: own elaboration

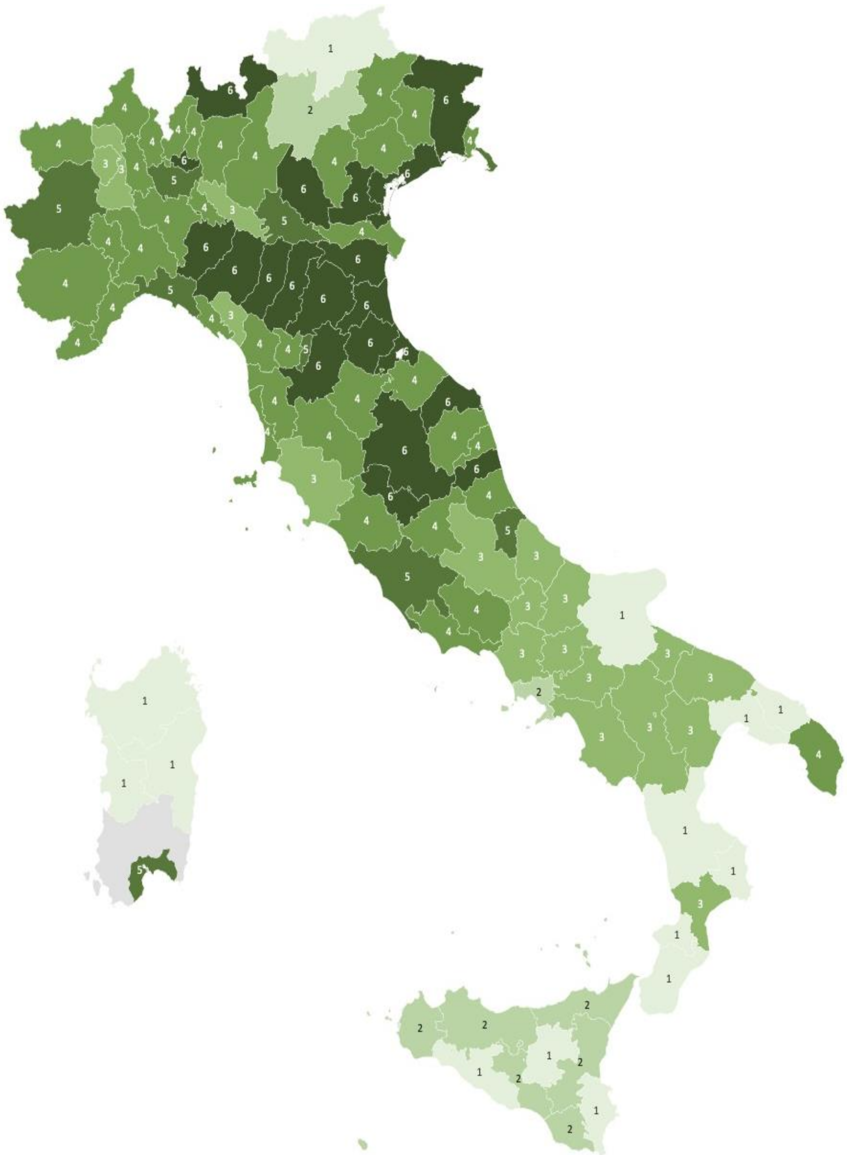
The provinces that belong to cluster VI are the following: Forlì-Cesena, Rimini, Piacenza, Ravenna, Reggio Emilia, Ferrara, Modena, Parma, Sondrio, Monza and Brianza, Udine, Perugia, Terni, Ascoli Piceno, Padua, Venice, Bologna, Ancona and Florence.

Figure 25: cluster VI

Source: own elaboration

Therefore, I realised a map to better visualize how the various provinces are divided into 6 clusters, each province has been numbered with the cluster to which it belongs as the color gradation alone does not make the division clear and sharp enough. Results are displayed in Figure 26.

Figure 26: map of Italy divided according to the clusters to which the provinces belong.

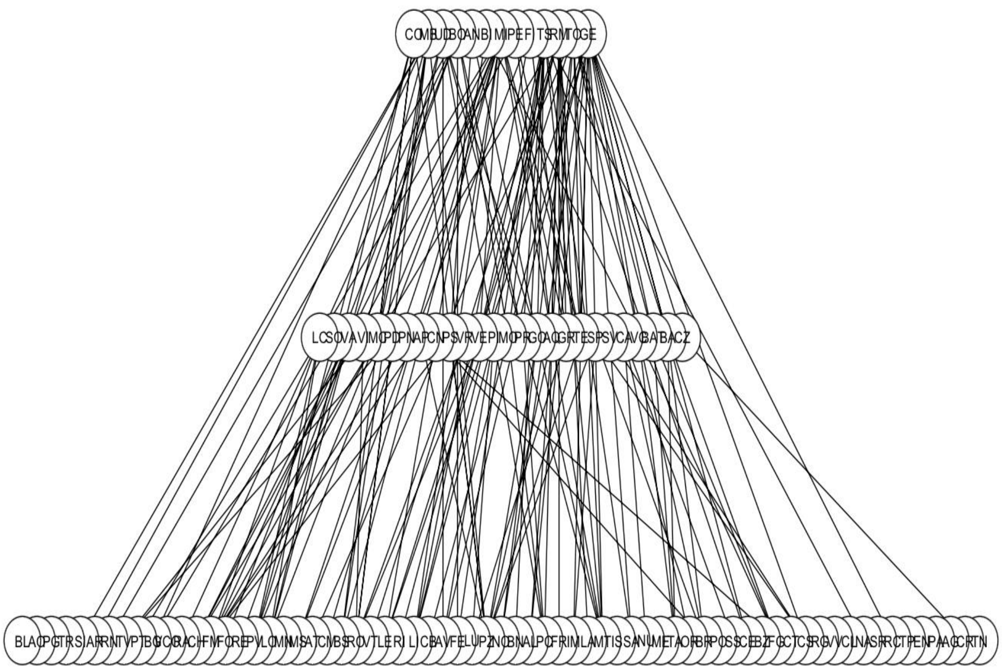


Source: own elaboration.

3.4 PoSet analysis

In the following chapter the analysis will be carried out using the Poset methodology, the R package used is “parsec” and the code was retrieved form Mazziotta’s book “Statistica per gli indici compositi”. Firstly, the whole dataset will be analysed, and the results are shown below in figure 27.

Figure 27: Hasse diagram for the whole dataset, absolute value.



Source: own elaboration.

The dataset was taken in percentages; thus, the dataset was considered in absolute value.

However, as the given diagram isn’t as easily interpretable a ranking was carried out with the “parsec” package. In order to have a better understanding the function “MRP” (Matrix of Mutual Ranking Probabilities) was performed, in particular the method used was “approximation”, given the dimensions of the dataset it was the optimal method to use, as recommended from previous literature on the topic. The results are shown in table III, it can be observed that the provinces with the highest rankings have the highest scores in the vector of dominance.

Table III: vector of dominance and ranking of the Italian provinces.

Code	Vector of dominance	Ranking
MC	0,1656	1
SA	0,1580	2
PO	0,1465	3
PN	0,1429	4
PI	0,1421	5
VCO	0,1336	6
VA	0,1281	7
TN	0,1209	8
VE	0,1075	9
SI	0,1033	10
BR	0,1020	11
CN	0,1020	12
GO	0,1018	13
FO	0,1018	14
RI	0,1009	15
AR	0,1005	16
LE	0,1005	17
AL	0,1005	18
RN	0,0999	19
NO	0,0999	20
LC	0,0995	21
CT	0,0994	22
CZ	0,0991	23
IS	0,0990	24
AV	0,0990	25

Code	Vector of dominance	Ranking
GE	0,0990	26
PA	0,0989	27
CS	0,0988	28
FG	0,0988	29
LO	0,0988	30
MO	0,0988	31
OR	0,0987	32
SV	0,0982	33
TO	0,0982	34
MB	0,0979	35
RA	0,0978	36
SS	0,0974	37
PG	0,0974	38
PS	0,0974	39
RC	0,0974	40
PV	0,0974	41
RM	0,0972	42
MT	0,0971	43
FE	0,0962	44
BS	0,0962	45
CE	0,0962	46
CM	0,0962	47
EN	0,0962	48
LA	0,0960	49
UD	0,0957	50
BI	0,0953	51
PZ	0,0951	52
BO	0,0940	53
SP	0,0935	54
SR	0,0933	55
NA	0,0932	56
NU	0,0932	57
TV	0,0924	58
ME	0,0923	59
MN	0,0916	60
LI	0,0916	61
FI	0,0912	62
VR	0,0910	63

Code	Vector of dominance	Ranking
MI	0,0906	64
RO	0,0905	65
AN	0,0898	66
AO	0,0898	67
AP	0,0898	68
AQ	0,0898	69
AT	0,0898	70
BA	0,0898	71
BAT	0,0898	72
BG	0,0898	73
BL	0,0898	74
BZ	0,0898	75
PC	0,0898	76
RG	0,0898	77
CA	0,0898	78
CL	0,0898	79
CO	0,0898	80
TR	0,0898	81
VC	0,0898	82
VT	0,0898	83
VV	0,0898	84
AG	0,0898	85
TS	0,0893	86
PR	0,0872	87
IM	0,0869	88
LU	0,0868	89
TP	0,0867	90
SO	0,0866	91
PD	0,0860	92
PE	0,0860	93
FR	0,0847	94
VI	0,0845	95
RE	0,0842	96
TA	0,0837	97
TE	0,0834	98
FM	0,0833	99
CH	0,0826	100
BN	0,0761	101

Code	Vector of dominance	Ranking
CB	0,0753	102
MS	0,0714	103
CR	0,0707	104
PT	0,0531	105
GR	0,0387	106

Source: own elaboration.

Macerata is ranked as first in among the Italian provinces meanwhile Grosseto is ranked in the last position.

Moreover, in the table III.a) the descriptive statistics of the previous results will be reported.

Table III.a: descriptive statistics of the vector of dominance

Average	0,0957
Standard error	0,0016
Median	0,0937
Mode	0,0898
Standard deviation	0,0166
Sample Variance	0,0003
Kurtosis	6,6334
Asymmetry	1,4678
Interval	0,1268
Minimum	0,0387
Maximum	0,1656

Source: own elaboration

The previous table summarizes the descriptive statistics, and a few results shall be pointed out such as: maximum of 0,1656 that corresponds to Macerata and the minimum of 0,0387 to Grosseto. The mean in this case is of 0,0898 and the provinces that have the same score are 20, which are: Ancona, Aosta, Ascoli

Piceno, Aquila, Asti, Bari, Berletta-Adria-Trani, Bergamo, Belluno, Bolzano, Piacenza, Ragusa, Cagliari, Caltanissetta, Como, Trapani, Vercelli, Viterbo, Vibo Valentia and Agrigento.

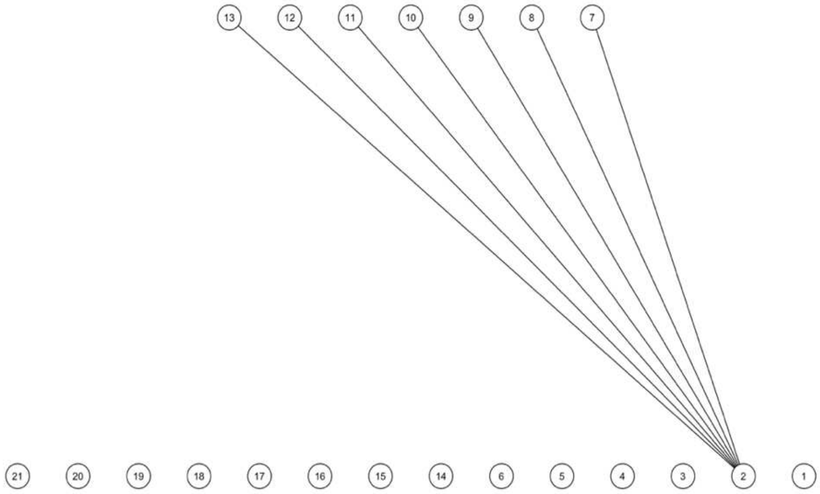
The legend in the table III. b represents the numbers that refer to the different Italian regions.

Table III.b: legend of the hasse diagram for Italy, divided by regions.

Abruzzo	1
Basilicata	2
Bolzano	3
Calabria	4
Campania	5
Emilia-Romagna	6
Friuli-Venezia Giulia	7
Lazio	8
Liguria	9
Lombardia	10
Marche	11
Molise	12
Piemonte	13
Puglia	14
Sardegna	15
Sicilia	16
Toscana	17
Trento	18
Umbria	19
Valle d'Aosta	20
Veneto	21

Source: own elaboration.

Figure 29: Hasse diagram for Italy, divided by region.



Source: own elaboration

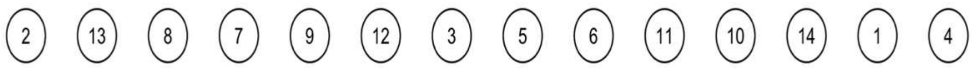
Table IV: vector of dominance and ranking of Italy divided by regions.

Region	Vector of dominance	Ranking
Piemonte	0,2379	1
Friuli-Venezia Giulia	0,2379	2
Lazio	0,2379	3
Liguria	0,2379	4
Lombardia	0,2379	5
Marche	0,2379	6
Molise	0,2379	7
Abruzzo	0,2149	8
Bolzano	0,2149	9
Calabria	0,2149	10
Campania	0,2149	11
Emilia-Romagna	0,2149	12
Puglia	0,2149	13
Sardegna	0,2149	14
Sicilia	0,2149	15
Toscana	0,2149	16
Trento	0,2149	17
Umbria	0,2149	18
Valle d'Aosta	0,2149	19
Veneto	0,2149	20

Source: own elaboration.

Initially the intention was to recreate through the PoSet methodology the partial ranking order of the cluster groups, however, after analysing the results[2] it was decided to proceed differently due to the disappointing results. In figure 30 the result of "Cluster 1" will be shown.

Figure 30: Hasse diagram of Cluster 1



Source: own elaboration. Legend: AG=1; BR=2; BZ=3; CR=4; CS=5; EN=6; FG=7; NU=8; OR=9; RC=10; SR=11; SS=12; TA=13; VV=14

Furthermore, the dataset was sub-divided into 5 zones (NUTS1 defined. By Eurostat), to better understand how the various provinces position themselves in the ranking. The 5 zones are the following: north-west, north-east, center, south and islands.

The north-west contains the following regions: Valle d'Aosta, Liguria, Lombardia e Piemonte.

The north-east: Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, Emilia-Romagna.

2 The PoSet methodology was applied to the rest of the clusters too, however due to the poor results only "Cluster 1" is be reported in the thesis.

The center: Umbria, Toscana, Marche e Lazio.

The south: Campania, Abruzzo, Molise, Basilicata, Puglia and Calabria.

The islands: Sardegna and Sicilia.

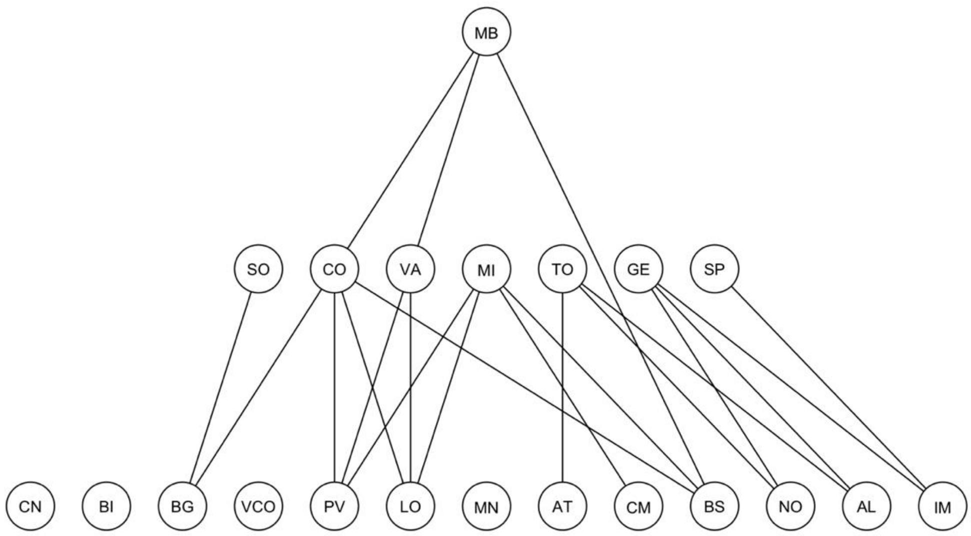
The division was taken from the Eurostat side, in particular the NUTS1. In the case of the zones the method used in the code is "exact" rather than "approximate" as the datasets are adequate due to the smaller size.

3.4.1 Zones

North-west

Figure 31 reports the result of the PoSet ranking is shown through the Hasse diagram for the north-west zone of the Italian provinces (21 provinces).

Figure 31: Hasse diagram for the north-west zone.



Source: own elaboration.

In order to provide a clearer understanding of the ranking, although it is already fairly evident in the Hasse diagram, the ranking has been compiled in table VI. Torino is in the first place among the 21 north-west provinces with a score of 0,3152, meanwhile Lodi is in the last position with a score of 0,1232.

Table VI: vector of dominance and ranking of the Italian provinces in the north-west zone.

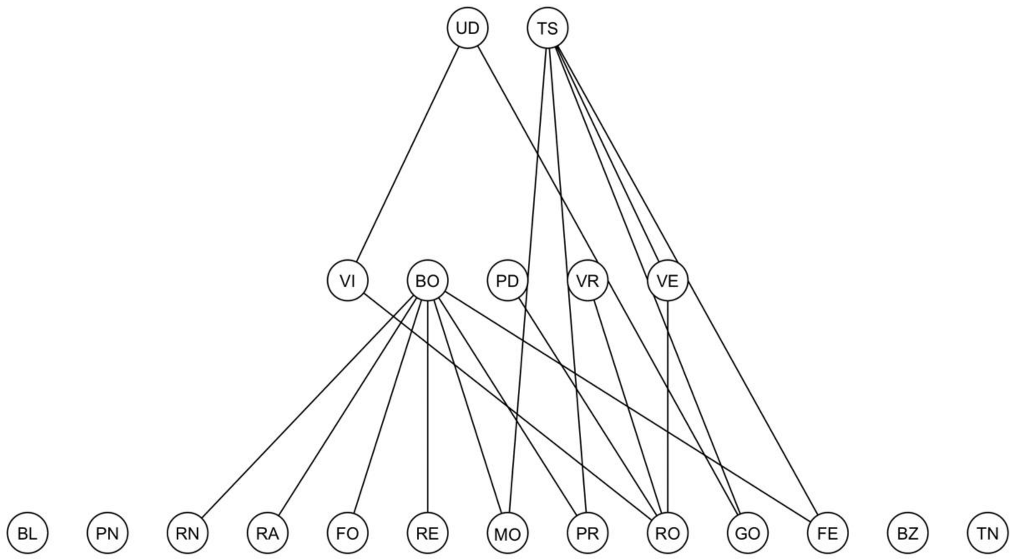
CODE	VECTOR OF DOMINANCE	RANKING
TO	0,3152	1
NO	0,2979	2
MB	0,2901	3
BS	0,2871	4
VA	0,2758	5
SP	0,2385	6
VCO	0,2373	7
BI	0,2365	8
GE	0,2079	9
MI	0,2079	10
PV	0,2079	11
SO	0,2079	12
CN	0,1906	13
CO	0,1878	14
BG	0,1640	15
AT	0,1640	16
MN	0,1604	17
AL	0,1544	18
CM	0,1486	19
IM	0,1232	20
LO	0,1232	21

Source: own elaboration.

North-east

In the following diagram the result of the PoSet ranking is shown through the Hasse diagram for the north-east zone of the Italian provinces (20 provinces).

Figure 32: Hasse diagram for the north-east zone.



Source: own elaboration.

As it can be seen, in this case the ranking is clearly readable, and the ranking will be shown in table VII.

Udine is in the first place among the 20 north-est provinces with a score of 0,3536, meanwhile Forlì-Cesena is in the last position with a score of 0,0724.

Table VII: vector of dominance and ranking of the Italian provinces in the north-east zone.

CODE	VECTOR OF DOMINANCE	RANKING
UD	0,3536	1
PN	0,3374	2
VI	0,2881	3
RN	0,2247	4
TS	0,2247	5
RA	0,2144	6
TN	0,2110	7
BL	0,2110	8
BO	0,2110	9
VR	0,2110	10
PD	0,2059	11
PR	0,2059	12
RE	0,2059	13
RO	0,2059	14
VE	0,2022	15
BZ	0,1893	16
GO	0,1893	17
MO	0,1893	18
FE	0,1730	19
FO	0,0724	20

Source: own elaboration.

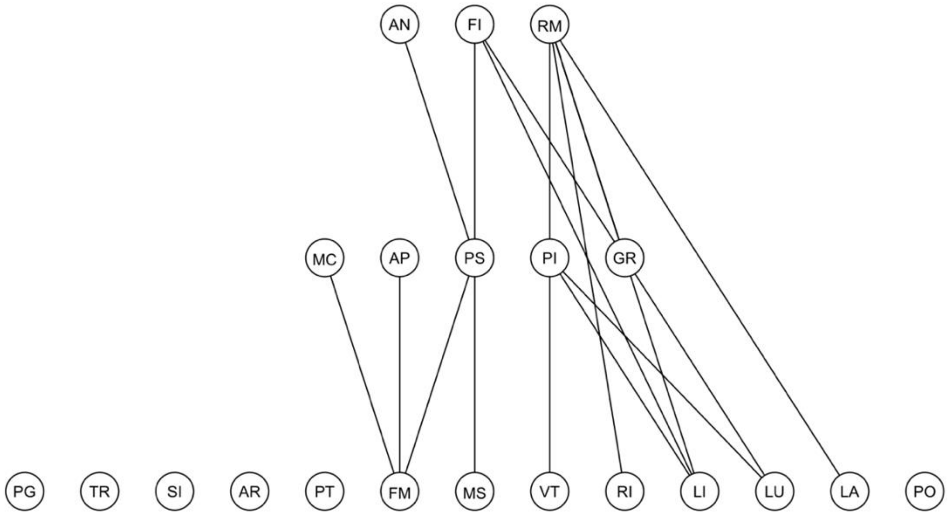
Center

Figure 33 summarizes the result of the PoSet ranking through the Hasse diagram for the center zone for 21 Italian provinces.

To ensure a clearer comprehension of the ranking, even though the Hasse diagram already illustrates it well, the ranking is shown in table VIII.

Lucca is in the first place among the 21 center provinces with a score of 0,3389, meanwhile Massa-Carrara is in the last position with a score of 0,0936.

Figure 33: Hasse diagram for the center zone.



Source: own elaboration.

Table VIII: vector of dominance and ranking of the Italian provinces in the center zone.

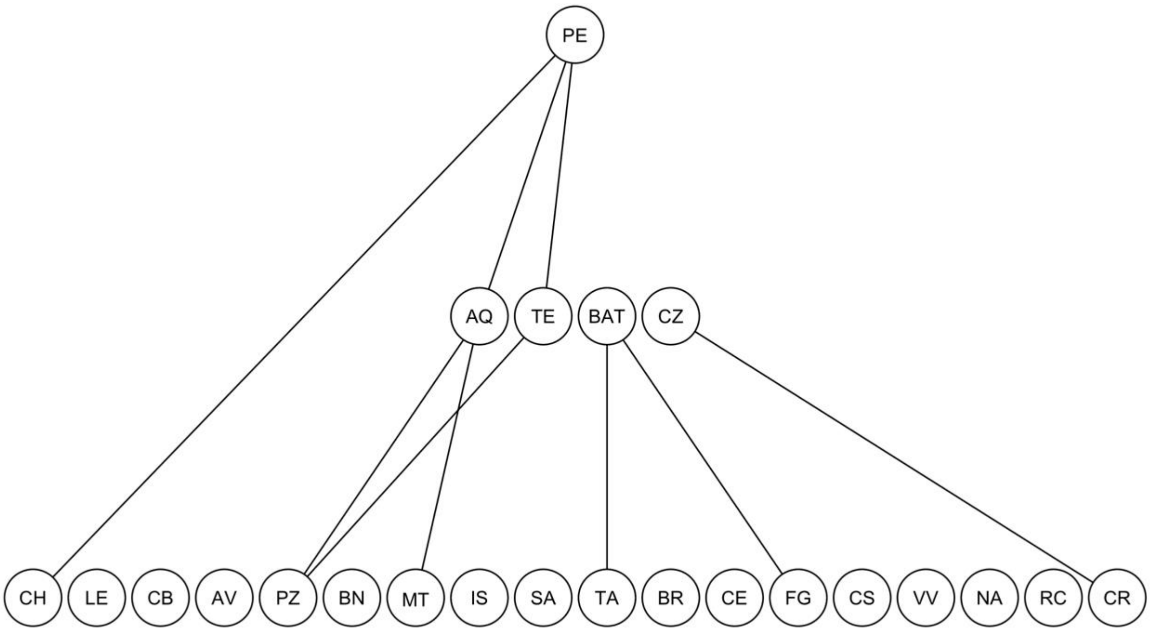
CODE	VECTOR OF DOMINANCE	RANKING
LU	0,3389	1
PG	0,3093	2
PS	0,2629	3
MC	0,2598	4
RI	0,2280	5
TR	0,2280	6
RM	0,2094	7
PI	0,2094	8
PT	0,2094	9
SI	0,2094	10
VT	0,2094	11
AN	0,2094	12
GR	0,2037	13
PO	0,2020	14
AP	0,2017	15
FM	0,2017	16
LA	0,2017	17
LI	0,1931	18
FI	0,1482	19
AR	0,1164	20
MS	0,0936	21

Source: own elaboration.

South

Diagram 34 reports the result of the PoSet ranking for the south zone of the 23 Italian provinces.

Figure 34: Hasse diagram for the south zone.



Source: own elaboration.

To facilitate a clearer understanding of the ranking, despite the clarity of the Hasse diagram, the ranking is shown in the table IX.

Vibo Valentia is in the first place among the 23 south provinces with a score of 0,3300, meanwhile Napoli is in the last position with a score of 0,1051.

Table IX: vector of dominance and ranking of the Italian provinces in the south zone.

CODE	VECTOR OF DOMINANCE	RANKING
VV	0,3300	1
LE	0,2947	2
CE	0,2649	3
TA	0,2512	4
RC	0,2251	5
BAT	0,2022	6
BN	0,2022	7
BR	0,2022	8
CZ	0,2022	9
FG	0,2022	10
MT	0,2022	11
PE	0,2022	12
PZ	0,2022	13
SA	0,2022	14
CH	0,2022	15
CR	0,2022	16
AV	0,2022	17
TE	0,1775	18
CS	0,1574	19
CB	0,1574	20
AQ	0,1413	21
IS	0,1321	22
NA	0,1051	23

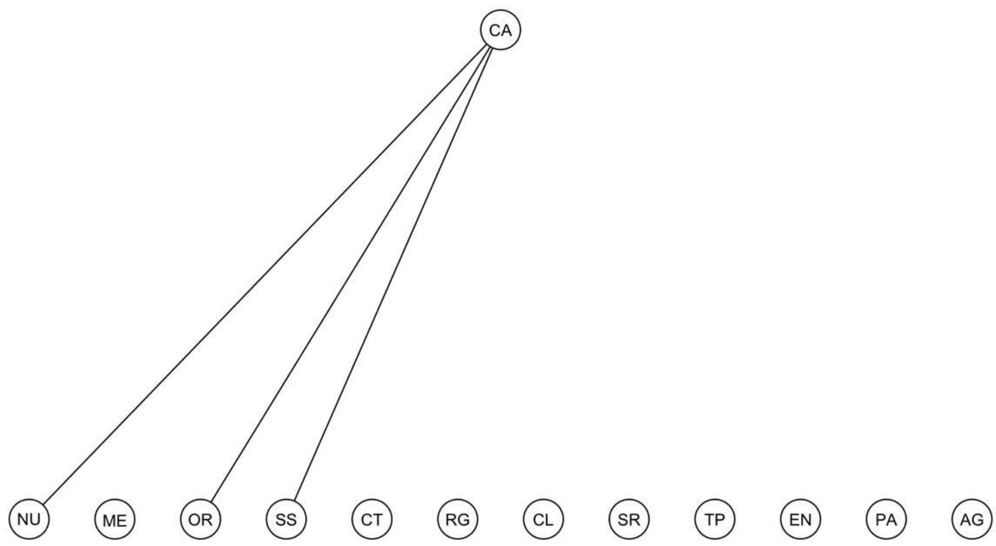
Source: own elaboration.

Islands

Figure 35 reports the results for 13 provinces in the islands zone.

Despite the Hasse diagram is easily interpretable, due to the small amount of chains present, the ranking is listed below in table X.

Figure 35: Hasse diagram for the islands zone.



Source: own elaboration.

Table X: vector of dominance and ranking of the Italian provinces in the islands zone.

CODE	VECTOR OF DOMINANCE	RANKING
TP	0,4232	1
AG	0,2726	2
CL	0,2726	3
CT	0,2726	4
EN	0,2726	5
ME	0,2726	6
NU	0,2726	7
OR	0,2726	8
SR	0,2726	9
CA	0,2726	10
SS	0,2253	11
PA	0,2253	12
RG	0,2253	13

Source: own elaboration.

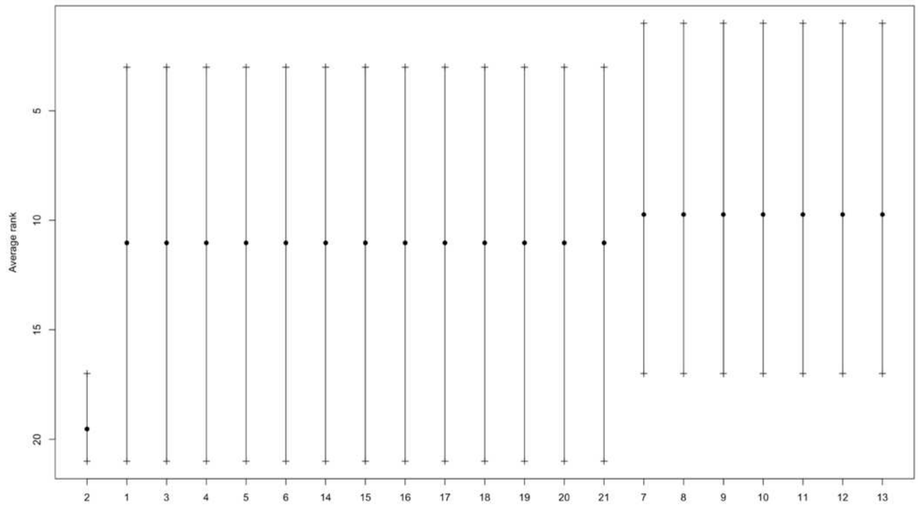
Trapani is in the first place among the 13 islands provinces with a score of

0,4232, meanwhile Ragusa is in the last position with a score of 0,2253.

3.4.2 Ranking distribution

Ranking distribution of Italy, divided by regions.

Figure 36: ranking distribution of the Italian regiones.

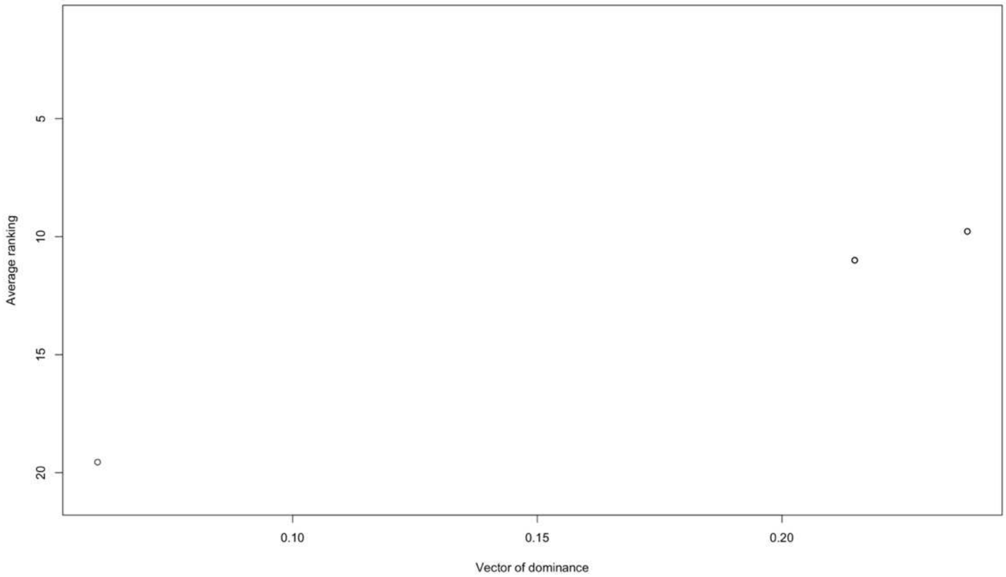


Source: own elaboration. Legend: Abruzzo=1; Basilicata=2; Bolzano=3; Calabria=4; Campania=5; Emilia-Romagna =6; Friuli-Venezia Giulia =7; Lazio=8; Liguria=9; Lombardia=10; Marche=11; Molise=12; Piemonte=13; Puglia=14; Sardegna=15; Sicilia=16; Toscana=17; Trento=18; Umbria=19; Valle d'Aosta=20; Veneto=21

The ranking distribution of the Italian regions plot shows that the ordinate scale of the graph above starts from the number of observations, in our case 21, which also symbolizes the last position (2, Basilicata). The ranking represents the best condition with the first position being the region denoted as 13, which is

Piemonte.

Figure 37: comparison between average ranking and the vector of dominance, Italy divided by regions.



Source: own elaboration

Table X: row sums of Italy, divided by regions.

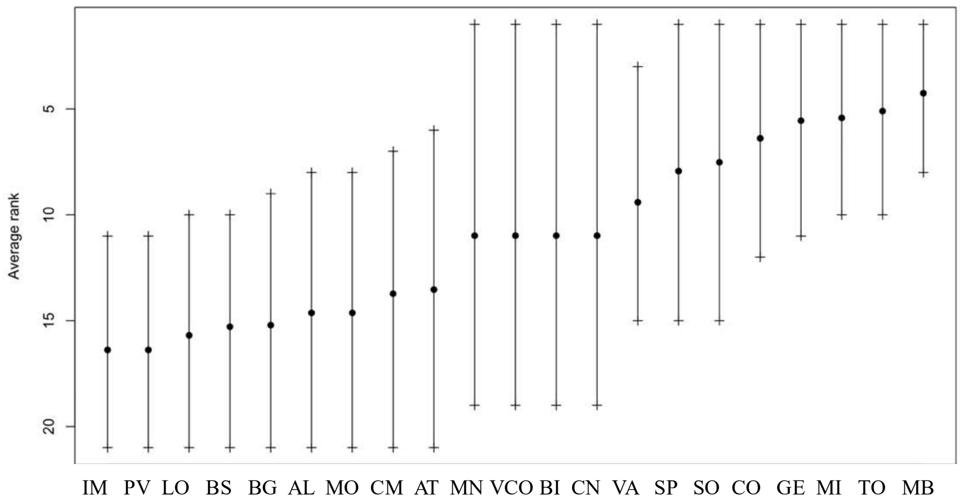
1	2	3	4	5	6	7	8	9	10
11.0000	19.5556	11.0000	11.0000	11.0000	11.0000	9.7778	9.7778	9.7778	9.7778
11	12	13	14	15	16	17	18	19	20
9.7778	9.7778	9.7778	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000	11.0000
21									
11.0000									

Source: own elaboration

The higher dominance of a region seems to be directly correlated with a better average ranking. This is evident in the progression of the data points.

Ranking distribution of the Italian provinces, zones.

Figure 38: ranking distribution of the north-west provinces

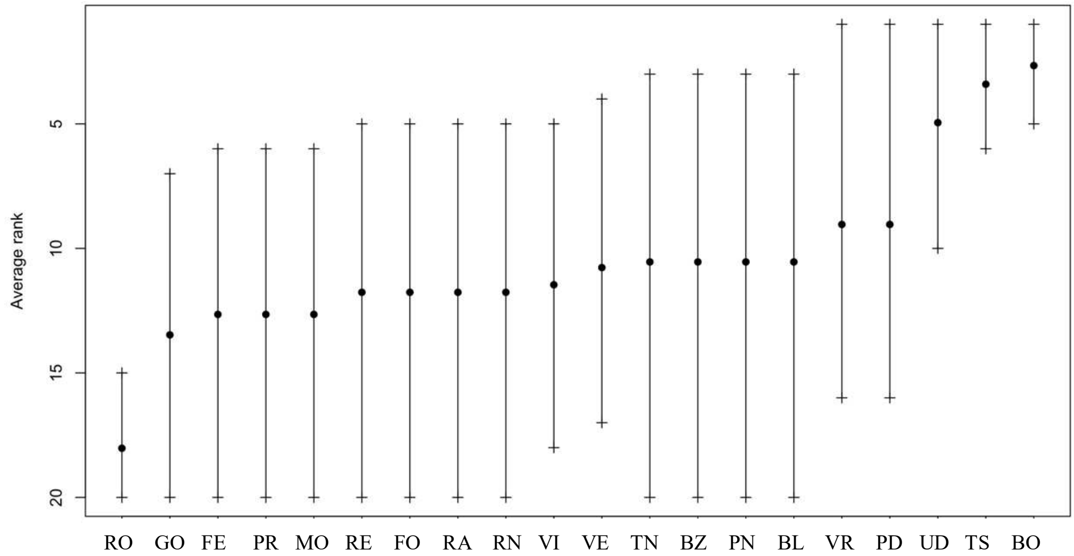


Source: own elaboration.

The ranking distribution of the north-west provinces plot shows that the ordinate scale of the graph above starts from the number of observations, in this case 21, which also symbolizes the last position (11, Lecco). The ranking represents the best condition with the first position being the region denoted as 12, which is Monza e della Brianza.

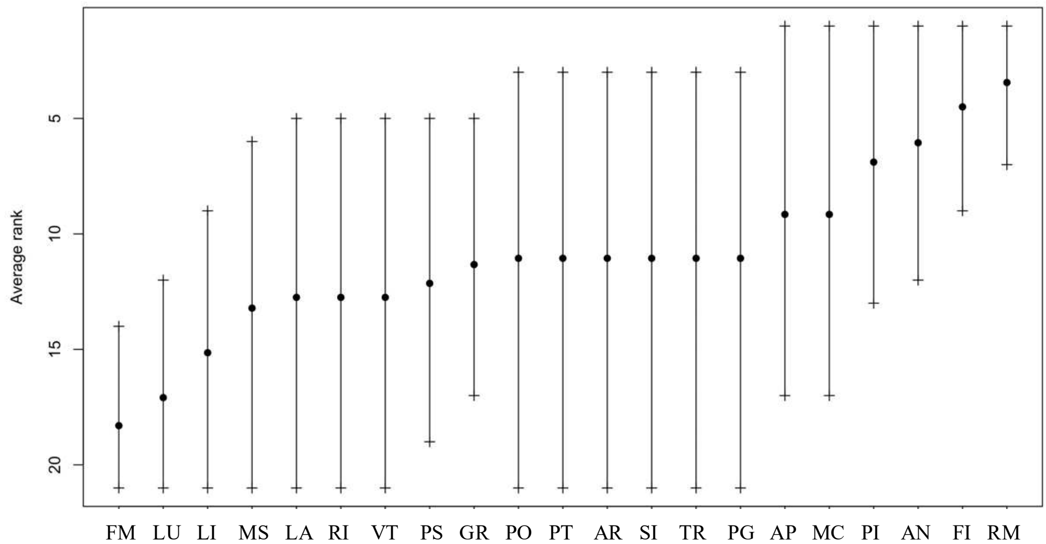
The ranking distribution of the north-east provinces plot shows that the ordinate scale of the graph above starts from the number of observations, in this case 20, which also symbolizes the last position (14, Rovigo). The ranking represents the best condition with the first position being the region denoted as 2, which is Bologna.

Figure 39: ranking distribution of the north-east provinces



Source: own elaboration.

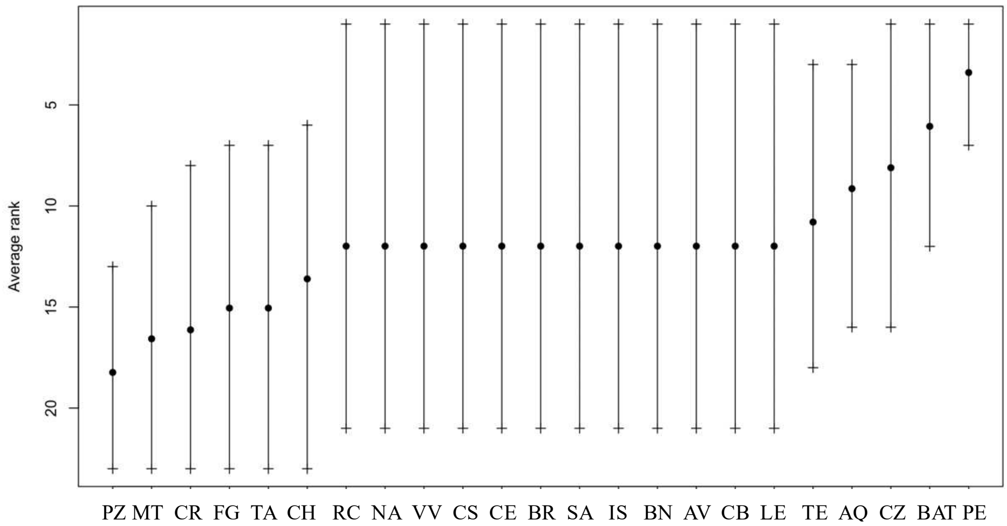
Figure 40: ranking distribution of the center provinces



Source: own elaboration.

The ranking distribution of the center provinces plot shows that the ordinate scale of the graph above starts from the number of observations, in this case 21, which also symbolizes the last position (5, Fermo). The ranking represents the best condition with the first position being the region denoted as 18, which is Rome.

Figure 41: ranking distribution of the south provinces

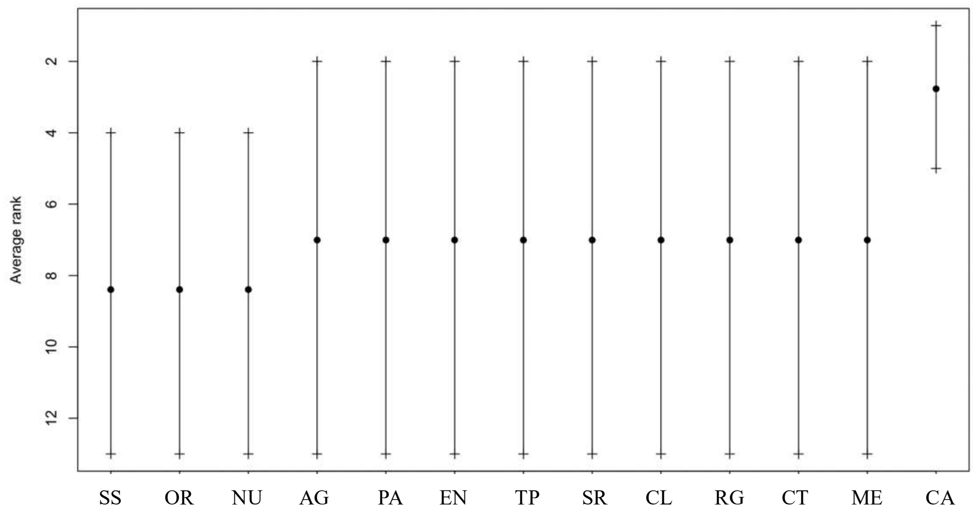


Source: own elaboration.

The ranking distribution of the south provinces plot shows that the ordinate scale of the graph above starts from the number of observations, in this case 23, which also symbolizes the last position (18, Potenza). The ranking represents the best condition with the first position being the region denoted as 17, which is Pescara.

The ranking distribution of the south provinces plot shows that the ordinate scale of the graph above starts from the number of observations, in this case 13, which also symbolizes the last position (12, Sassari). The ranking represents the best condition with the first position being the region denoted as 2, which is Cagliari.

Figure 42: ranking distribution of the islands' provinces



Source: own elaboration.

Chapter 4

CONCLUSION

4.1 Summary of Findings

The aim of this thesis was to examine the effects of the digitalization strategies on the sustainable development among the Italian provinces.
The main goal was to develop a strategy that would allow to evaluate the impact of digitalization on the sustainable development, regarding the SDG indicators that were defined by Agenda 2030.
The main approach was based on the partially ordered systems (PoSet).
The analysis that was carried out highlighted the significant correlation between technological progress and the achievement of the SGD's, among them education (SDG 4), industrial innovation (SDG 9), health and well-being (SDG 3).

This statement underlines the fundamental role played by digitalization as the enabling engine of sustainable development.
The analysis was conducted using the statistical software R, which enabled a rigorous examination of the data.

The Italian provinces were grouped into six clusters, based on the indicators SDG and BEST. In particular, the clustering highlighted that the north-center provinces, like Torino (To), Pavia (PV) and Udine (UD), tend to score higher in terms of digital dominance, thanks to factor such as fixed network coverage, the highest percentage of graduates and ICT basic skills along with a higher participation in continuing education. On the opposite, the south and islands province, such as Vibo Valentia (VV), Napoli (NA) and Ragusa (RG) show a significant delay in the digital development, often due to a low diffusion of technology.

In addition, the descriptive statistics show significant differences among the provinces, with scores that vary from 15,4% for the FNC index (Nuoro, NU) up to 86,6% (Prato, PO), along with differences in the percentages of college graduates, Taranto (TA) with 13,2% meanwhile in bologna 42,3%.

From the territorial point of view, the north-west and north-east regions show leadership in digitization compared to southern and island regions. This gap highlights the need for targeted policies to close territorial inequalities.

The PoSet approach was also applied at the level of geographic areas, NUTS1 (North-west, North-east, Center, South and Islands), allowing for a more granular view of development dynamics among provinces belonging to each area. In particular, the Northwest saw Turin leading the ranking, while Lodi occupied the last position. In the Northeast, Udine ranked first, while Forlì-Cesena was the province with the lowest scores.

The most important aim will be to develop a more effective and targeted local strategy that would spread digitization evenly across the country. Policy makers shouldn't only focus on expanding technology infrastructure, such as broadband, but also on education initiatives and the adoption of new technologies in less developed areas.

In conclusion, this research has highlighted how digitization, when accompanied by appropriate training and infrastructure policies, can be a driver for sustainable growth.

The main challenge that needs to be faced by the Italian policy makers remains bridging territorial disparities, ensuring that all Italian provinces can benefit from the opportunities offered by the digital transition.

4.2 Implications and Recommendations

This study should not be understood as a static representation of the results achieved in a given period of time, but as a dynamic evaluation methodology that could lead over time to the selection of new sets of indicators, also selecting them from the new indices that will be made available in the future by ISTAT or Eurostat, and new dimensions of analysis to monitor the progress of digitainability.

As was demonstrated by this thesis, the profile of the same province or region can vary over time, as the development and digitization strategies adopted by them vary.

A potential future development of this research could involve expanding the set of indicators used, particularly by including new variables that better reflect realities at the provincial level. One of the few limitations encountered was the unavailability of certain data at the provincial level: 3 out of the 9 variables used were only available at the regional level, in particular BDS, SDY and IU. Integrating these variables at the provincial level would provide a more accurate and detailed representation of the degree of development and digitalization of the territories.

A possible extension to this thesis could be transforming the datasets in deciles and re-analysing how the different provinces and regions position themselves within the ranking as this method may offer a different perspective on how to compare the different Italian territories. Another interesting extension might be an overtime comparison of the provinces and regions, and understand how the digitalization influenced the achievement of the SDG's overtime, for example over a five years span. It could bring out the trends and the potential changes, especially if the policy makers start to invent in the less digitalized territories.

Bibliography

Alaimo, L. S., & Maggino, F. (2020). Sustainable development goals indicators at territorial level: Conceptual and methodological issues—The Italian perspective. Social Indicators Research, 147(2), 383-419.

Albo, Y., Lanir, J., & Rafaeli, S. (2019). A conceptual framework for visualizing composite indicators. Social Indicators Research, 141, 1-30.

Aparicio, J., & Kapelko, M. (2019). Enhancing the measurement of composite indicators of corporate social performance. Social Indicators Research, 144, 807-826.

Arcagni, A., Cavalli, L., & Fattore, M. (2021). Partial order algorithms for the assessment of Italian cities sustainability.

Aristovnik, A., Kovač, P., Murko, E., Ravšelj, D., Umek, L., Bohatá, M., Hirsch B., Schäfer F., & Tomaževič, N. (2021). The use of ICT by local general administrative authorities during Covid-19 for a sustainable future: Comparing five European countries. Sustainability, 13(21), 11765.

Bahr, P. R., Bielby, R., & House, E. (2011). The use of cluster analysis in typological research on community college students. New Directions for Institutional Research, 2011(S1), 67-81.

Baldazzi, B., Bartoloni, M., Carbonara, M., Carulli, A. L., Conigliaro, P., Costa, R., Di Biagio L., Pallotti A., Saviolini M., Taralli S., & Tinto, A. (2019). Methods and models to evaluate territorial inequalities in well-being. Work in progress of a thematic research project. RIEDS-Rivista Italiana di Economia, Demografia e Statistica-The Italian Journal of Economic, Demographic and Statistical Studies, 73(2), 39-50.

Bican, P. M., & Brem, A. (2020). Digital business model, digital transformation, digital entrepreneurship: Is there a sustainable "digital"?. Sustainability, 12(13), 5239.

Bruggemann, R., & Annoni, P. (2014). Average heights in partially ordered sets. MATCH Commun Math Comput Chem, 71, 117-142.

Brüggemann, R., & Carlsen, L. (2011). An improved estimation of averaged ranks of partial orders. MATCH Communications in Mathematical and in Computer Chemistry, 65, 383-414.

Brüggemann, R., Bücherl, C., Pudenz, S., & Steinberg, C. E. W. (1999). Application of the concept of partial order on comparative evaluation of environmental chemicals. Acta hydrochimica et hydrobiologica, 27(3), 170-178.

Brüggemann, R., Carlsen, L., Beycan, T., Suter, C., & Maggino, F.

(Eds.). (2021). Measuring and Understanding Complex Phenomena: Indicators and Their Analysis in Different Scientific Fields. Springer Nature.

Brüggemann, R., Carlsen, L., & Wittmann, J. (Eds.). (2013). Multi-indicator systems and modelling in partial order. Springer Science & Business Media.

Brüggemann, R., Carlsen, L., Voigt, K., & Wieland, R. (2014). PyHasse software for partial order analysis: Scientific background and description of selected modules. Multi-indicator systems and modelling in partial order, 389-423.

Brüggemann, R., Patil, G. P. (2011). Ranking and prioritization for multi-indicator systems: Introduction to partial order applications. Springer Science & Business Media.

Brüggemann, R., Sørensen, P. B., Lerche, D., & Carlsen, L. (2004). Estimation of averaged ranks by a local partial order model. Journal of chemical information and computer sciences, 44(2), 618-625.

Çağlar, M., & Gürler, C. (2022). Sustainable Development Goals: A cluster analysis of worldwide countries. Environment, development and sustainability, 24(6), 8593-8624.

Camera dei Deputati. (2022). L'agenda globale per lo sviluppo sostenibile (Sesta edizione n. 89). Documentazione e ricerche, XVIII Legislatura.

Camodeca, R., & Almici, A. (2021). Digital transformation and convergence toward the 2030 agenda's sustainability development goals: evidence from Italian listed firms. Sustainability, 13(21), 11831.

Chevalier, J. M. (2019). Participatory action research: Theory and methods for engaged inquiry. Routledge.

D'Amico, G., Szopik-Depczyńska, K., Beltramo, R., D'Adamo, I., & Ioppolo, G. (2022). Smart and sustainable bioeconomy platform: A new approach towards Sustainability. Sustainability, 14(1), 466.

De Siqueira, G., Malaj, S., & Hamdani, M. (2022). Digitalization, Participation and Interaction: Towards More Inclusive Tools in Urban Design—A Literature Review. Sustainability 2022, 14, 4514.

Dewett, T., & Jones, G. R. (2001). The role of information technology in the organization: a review, model, and assessment. Journal of management, 27(3), 313-346.

Ding, C., Liu, C., Zheng, C., & Li, F. (2021). Digital economy, technological innovation and high-quality economic development: Based on spatial effect and mediation effect. Sustainability, 14(1), 216.

Dziatkovskii, A. (2023). Trends in informatization of education for sustainable development. Символ науки, (6-1), 125-131.

Esses, D., Csete, M. S., & Németh, B. (2021). Sustainability and digital transformation in the Visegrad group of center European countries. Sustainability, 13(11), 5833.

European Commission. (2020). Delivering on the UN's Sustainable Development Goals – A comprehensive approach.

European Parliament. (2022). Fit for 55 package – Towards climate neutrality (Briefing).

Eurostat. (2023). Sustainable development in the European Union – Monitoring report on progress towards the SDGs in an EU context.

Farahani, M. S., Esfahani, A., Moghaddam, M. N. F., & Ramezani, A. (2022). The impact of Fintech and artificial intelligence on COVID 19 and sustainable development goals. International Journal of Innovation in Management, Economics and Social Sciences, 2(3), 14-31.

Fattore, M., & Arcagni, A. (2018). Using mutual ranking probabilities for dimensionality reduction and ranking extraction in multidimensional systems of ordinal variables. *Advances in Statistical*

Modelling of Ordinal Data, 117.

Fattore, M. (2013). La valutazione statistica del benessere: ordinamenti parziali e nuovi paradigmi metodologici. Lavoro, economia, finanza, 10.

Fattore, M. (2017). Synthesis of indicators: The non-aggregative approach. Complexity in society: From indicators construction to their synthesis, 193-212.

Fattore, M., Maggino, F., & Colombo, E. (2012). From composite indicators to partial orders: evaluating socio-economic phenomena through ordinal data. Quality of life in Italy: Research and reflections, 41-68.

Gretton, P., Gali, J., & Parham, D. (2004). The effects of ICTs and complementary innovations on Australian productivity growth. The Economic Impact of ICT: Measurement, evidence and implications, 105-30.

Gupta, S., & Rhyner, J. (2022). Mindful Application of Digitalization for Sustainable Development: The Digitainability Assessment Framework. Sustainability 2022, 14, 3114. Towards the Sustainability of AI, 67.

Gupta, S., Motlagh, M., & Rhyner, J. (2020). The digitalization sustainability matrix: A participatory research tool for investigating digitainability. Sustainability, 12(21), 9283.

Hollenstein, H. (2004). The decision to adopt information and communication technologies (ICT): firm-level evidence for Switzerland. OCDE (2004), The Economic Impact of ICT–Measurement, Evidence and Implications, OCDE, Paris, 37-60.

Kuusisto, M. (2017). Organizational effects of digitalization: A literature review. International journal of organization theory and behavior, 20(03), 341-362.

Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023). Unlocking sustainable value through digital transformation: An examination of ESG performance. Information, 14(8), 444.

Lichtenthaler, U. (2021). Digitainability: The combined effects of the megatrends digitalization and sustainability. Journal of Innovation Management, 9(2), 64-80.

Lin, L. H., & Wang, K. J. (2022). Talent retention of new generations for sustainable employment relationships in work 4.0 Era—Assessment by Fuzzy Delphi Method. Sustainability, 14(18), 11535.

Liu, K., Feng, Z., & Zhang, Q. (2023). Examining the role of digitalization and gig economy in achieving a low carbon society: an empirical study across nations. Frontiers in Environmental Science, 11, 1197708.

Madden, D. (2010). Ordinal and cardinal measures of health inequality: an empirical comparison. Health Economics, 19(2), 243-250.

Mazziotta, M., Pareto, A., Mazziotta, M., Mazziotta, M., Pareto, A., Mazziotta, M., & Pareto, A. (2020). *Gli indici sintetici / Mazziotta Matteo; Pareto Adriano*. G. Giappichelli Editore.

McAfee, A. P. (2006). Enterprise 2.0: The dawn of emergent collaboration. MIT Sloan management review.

Milana, C., & Zeli, A. (2004). Productivity slowdown and the role of ICT in Italy: A firm-level analysis.

OECD. (2004). The Economic Impact of ICT: Measurement, Evidence and Implications.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. bmj, 372.

Pilat, D., & Devlin, A. (2004). The diffusion of ICT in OECD economies. The Economic Impact of ICT–Measurement, Evidence and Implications, 19-36.

Rogers, P. (2014). Theory of change: methodological briefs-impact evaluation No. 2 (No. innpub747).

Ruiz, F., El Gibari, S., Cabello, J. M., & Gómez, T. (2020). MRP-WSCI: Multiple reference point based weak and strong composite indicators. Omega, 95, 102060.

Smirlis, Y. (2020). A trichotomic segmentation approach for estimating composite indicators. Social Indicators Research, 150(2), 393-410.

Sobalkar, O. M., & Anekar, K. R. (2023). A study on United Nation's Sustainable Development Goals 2030 and its relationship with digital technology. EIIRJ.

Stein, D., & Valters, C. (2012). Understanding theory of change in international development.

Tokhir, S. B. (2023). Review of digitalization process in Uzbekistan. In Sustainable Economic Development of Regions: International and National Concepts.

Tu, Y. X., Kubatko, O., Piven, V., Kovalov, B., & Kharchenko, M. (2023). Promotion of sustainable development in the EU: Social and economic drivers. Sustainability, 15(9), 7503.

Valters, C. (2014). Theories of change in international development: Communication, learning, or accountability. JSRP Paper, 17, 1-29.

Villamil, C., Schulte, J., & Hallstedt, S. (2023). Implementing sustainability in product portfolio development through digitalization and a game-based approach. Sustainable Production and Consumption, 40, 277-296.

Vogel, I. (2012). Review of the use of 'Theory of Change'in international development. London: DFID.

Zhanbayev, R. A., Irfan, M., Shutaleva, A. V., Maksimov, D. G., Abdykadyrkyzy, R., & Filiz, Ş. (2023). Demoethical model of sustainable development of society: A roadmap towards digital transformation. Sustainability, 15(16), 12478.

Zhao, Q., Li, X., & Li, S. (2023). Analyzing the relationship between digital transformation strategy and ESG performance in large manufacturing enterprises: The mediating role of green innovation. Sustainability, 15(13), 9998.

Zola, C. (2023). Digitalization and contextual factors in Emilia-Romagna municipalities: A cluster and poset based approach. DEMB WORKING PAPER SERIES.

Sitography

Klaus Schwab: https://www.uniba.it/it/docenti/ciuffreda-antonio/attivita-didattica/la-quarta-rivoluzione-industriale.pdf

https://commission.europa.eu/strategy-and-policy/sustainable-development-goals/eu-whole-government-approach_en

https://asvis.it/notizie-sull-alleanza/19-11471/il-pnrr-si-muove-in-direzione-della-sostenibilita-ma-da-solo-non-basta-

https://commission.europa.eu/system/files/2022-06/2022-european-semester-country-report-italy_en.pdf

SDG report 2022: https://www.istat.it/en/publication/2022-sdgs-report-statistical-information-for-2030-agenda-in-italy/

SDG report 2024: https://www.istat.it/produzione-editoriale/rapporto-sdgs-2024/

https://webthesis.biblio.polito.it/secure/31131/1/tesi.pdf

Appendix 1: datasets

Italian provinces dataset

CODE	PROVINCE	ALP	ANC	FNC	CGT	PCE	HSD	BDS	SDY	IU
AG	Agrigento	44,7	34,3	31,8	21,7	6,7	55,6	34	21,5	81,3
AL	Alessandria	60,6	55,8	35,4	24,7	6,1	60,3	48,7	18,4	85,4
AN	Ancona	67,5	65,9	60	38,3	12,1	73,1	46	13,8	85,9
AO	Aosta	72,5	69,6	39,7	30,2	10,2	62,1	50,3	13,5	77,5
AP	Ascoli Piceno	68,2	65,7	53,1	34,7	8,8	65,6	46	13,8	85,9
AQ	L'Aquila	62,8	56,3	47,40	28,6	11,6	68,3	43,1	16,4	84,2
AR	Arezzo	67,8	64,6	37,5	32,7	7,3	62,2	49,8	15,9	77,7
AT	Asti	63,6	59	35,7	26,5	4,8	60,5	48,7	18,4	85,4
AV	Avellino	61,9	52,7	41,1	27,2	8	63,9	34,2	8,4	87,4
BA	Bari	59,4	52,5	63,40	28,6	9,5	58,1	38,5	18,2	84,8
BAT	Barletta-Andria-Trani	59,4	52,7	63,20	25,5	7,9	49,7	38,5	18,2	84,8
BG	Bergamo	66,9	66,3	42,90	20,2	7,5	53,4	51	16,5	87
BI	Biella	67,3	62,6	59,00	25,4	11,7	60	48,7	18,4	85,4
BL	Belluno	73,1	73,9	33,90	28,2	7,7	69	50,1	13,5	80,5
BN	Benevento	61,3	52,5	45,20	35,4	10,4	59,8	34,2	8,4	87,4
BO	Bologna	68,5	66,5	61,70	42,3	16,1	74,6	51,2	3,1	86,6
BR	Brindisi	53,9	45,5	33,90	18,6	6,2	50,4	38,5	18,2	84,8
BS	Brescia	63,3	61,9	37,20	24,5	6,9	62,4	51	16,5	87
BZ	Bolzano	52,3	40,5	22,2	25,7	14,6	69,5	49,7	15,9	77,6
CA	Cagliari	59	48,5	75,30	36,7	22	63,3	45,4	19,7	82,2
CB	Campobasso	61	56,6	64,60	31,1	10,5	61,3	37,7	17	85,8
CE	Caserta	52,3	42,3	54,50	24,8	6,7	53,5	34,2	8,4	87,4
CH	Chieti	65	54,9	57,10	28,9	8,1	68,2	43,1	16,4	84,2

CODE	PROVINCE	ALP	ANC	FNC	CGT	PCE	HSD	BDS	SDY	IU
CL	Caltanissetta	48,9	36,5	54,20	20,8	6,3	45,6	34	21,5	81,3
CM	Cremona	63,4	59,8	57,70	24,4	5,4	56,8	51	16,5	87
CN	Cuneo	67,3	66,7	42,80	22,4	6,9	60,1	48,7	18,4	85,4
CO	Como	71,1	67,7	38,30	32,5	9,9	63,5	51	16,5	87
CR	Crotone	41,6	30,5	44,20	16,4	5,1	45,7	33,8	15,3	88,3
CS	Cosenza	50,3	39,9	21,30	25	7,4	58,9	33,8	15,3	88,3
CT	Catania	51,1	40,3	58,50	19,2	7,5	52	34	21,5	81,3
CZ	Catanzaro	52,2	42	47,70	22,6	6,4	57,2	33,8	15,3	88,3
EN	Enna	45,8	38,1	27,90	18,8	8	51,8	34	21,5	81,3
FE	Ferrara	61,6	59,9	46,30	30,7	12,4	62,6	51,2	3,1	86,6
FG	Foggia	51,6	41,9	42,50	18,3	4,6	47	38,5	18,2	84,8
FI	Firenze	65	64,2	63,70	38,5	12,4	72,8	49,8	15,9	77,7
FM	Fermo	65,9	64,4	30,30	24,4	8	58,5	46	13,8	85,9
FO	Forlì-Cesena	65,8	62,5	42,40	33	9,7	64,7	51,2	3,1	86,6
FR	Frosinone	59	48,5	40,80	27,5	8,2	68,4	52,9	16,7	87,1
GE	Genova	62,4	58,4	71,40	33,5	11,8	73,3	49,1	18,5	88,3
GO	Gorizia	62,8	60,8	42,70	26,1	9,6	67,7	52,3	14	88,3
GR	Grosseto	62,7	58,5	54,50	23	11	63,7	49,8	15,9	77,7
IM	Imperia	58,6	53,3	28,00	21,8	3,5	55,5	49,1	18,5	88,3
IS	Isernia	57,2	50,3	57,80	34,3	8,7	67,8	37,7	17	85,8
LA	Latina	58,1	48,9	42,80	23,3	10,9	58,1	52,9	16,7	87,1
LC	Lecco	71	71,6	33,10	34,5	9,6	63	51	16,5	87
LE	Lecce	62,3	55,8	23,50	20,1	7	52,5	38,5	18,2	84,8
LI	Livorno	62,1	56,8	37,30	23,5	10,5	67	49,8	15,9	77,7
LO	Lodi	64,2	62,2	30,20	23,8	6,7	57,1	51	16,5	87
LU	Lucca	61,5	57,4	36,80	21,9	10,7	60,5	49,8	15,9	77,7
MB	Monza e Brianza	70,9	70,3	46,80	38,9	8,8	72,3	51	16,5	87

CODE	PROVINCE	ALP	ANC	FNC	CGT	PCE	HSD	BDS	SDY	IU
MC	Macerata	68,7	66,9	38,00	28,1	8,1	62,4	46	13,8	85,9
ME	Messina	55,4	45,2	65,80	18,3	5,2	52,5	34	21,5	81,3
MI	Milano	67,1	65,3	76,70	39,3	12,5	71,9	51	16,5	87
MN	Mantova	64,1	61,1	80,10	24	7,3	59,4	51	16,5	87
MO	Modena	63,4	62,3	51,80	29,2	12,3	67,8	51,2	3,1	86,6
MS	Massa-Carrara	64,1	59,9	52,50	28,3	10	64,9	49,8	15,9	77,7
MT	Matera	57,6	47,6	43,10	25,6	9,3	63,8	36,1	12,4	83,7
NA	Napoli	48,8	38,5	73,20	21,5	6,4	49,3	34,2	8,4	87,4
NO	Novara	61,3	57,1	33,70	22,2	10,8	61	48,7	18,4	85,4
NU	Nuoro	55	44,1	15,40	25,3	9,1	47,2	45,4	19,7	82,2
OR	Oristano	53	41,8	16,80	26,5	7,8	48,2	45,4	19,7	82,2
PA	Palermo	45,8	34,8	76,30	20,6	5,4	51,9	34	21,5	81,3
PC	Piacenza	60,4	57,7	49,70	20,6	9,8	62,2	51,2	3,1	86,6
PD	Padova	68,3	68,2	54,70	36,3	13,6	66,6	50,1	13,5	80,5
PE	Pescara	66,9	58,9	68,10	30	12,7	72,3	43,1	16,4	84,2
PG	Perugia	70,2	65,8	50,70	32,9	12,2	72,1	50	16	70,8
PI	Pisa	65,4	63,9	40,40	35	13,2	69,7	49,8	15,9	77,7
PN	Pordenone	68,2	67	33,10	25,6	11,3	68,9	52,3	14	88,3
PO	Prato	53,5	59,6	86,60	19,2	7,4	51,4	49,8	15,9	77,7
PR	Parma	63,4	59,7	52,10	26,8	13,4	67	51,2	3,1	86,6
PS	Pesaro e Urbino	67,1	65,2	39,40	36,4	10,7	63,5	46	13,8	85,9
PT	Pistoia	67,1	63,8	37,10	21,5	11,6	58,7	49,8	15,9	77,7
PV	Pavia	64,4	60,7	23,90	25,1	7,4	61,5	51	16,5	87
PZ	Potenza	61,4	53,1	34,50	24,8	8,6	62,5	36,1	12,4	83,7
RA	Ravenna	66,4	65,5	54,40	27,8	8,8	66,2	51,2	3,1	86,6
RC	Reggio Calabria	47,9	35,9	40,70	25,5	9,2	56,6	33,8	15,3	88,3

CODE	PROVINCE	ALP	ANC	FNC	CGT	PCE	HSD	BDS	SDY	IU
RE	Reggio Emilia	64,4	63,6	54,9	29,1	8,7	67,9	51,2	3,1	86,6
RG	Ragusa	49,3	42,1	58,00	15,3	7	52,2	34	21,5	81,3
RI	Rieti	62,2	52,4	49,1	20,4	10,4	67,4	52,9	16,7	87,1
RM	Roma	65,3	58,5	76,9	39,7	12,6	75,2	52,9	16,7	87,1
RN	Rimini	67,8	63,9	38,7	36	8,3	67,3	51,2	3,1	86,6
RO	Rovigo	62,9	61,9	43,5	23,8	4,1	53,4	50,1	13,5	80,5
SA	Salerno	56,9	45,9	58,9	24,6	8,5	61,2	34,2	8,4	87,4
SI	Siena	68,3	67	38,4	27,1	6,5	64,9	49,8	15,9	77,7
SO	Sondrio	71,4	74,5	49,3	23,4	8,8	66,1	51	16,5	87
SP	La Spezia	61,7	55,1	36,50	29,3	13	73,7	49,1	18,5	88,3
SR	Siracusa	48,3	36,8	43,8	19,2	5,8	55,9	34	21,5	81,3
SS	Sassari	53,5	41,4	34	21,5	9,1	54,1	45,4	19,7	82,2
SV	Savona	60	58,5	23,2	28,6	14,9	66,4	49,1	18,5	88,3
TA	Taranto	54,3	44,8	45,7	13,2	5,5	49,4	38,5	18,2	84,8
TE	Teramo	62,2	57,7	35,5	28,3	10,5	64,7	43,1	16,4	84,2
TN	Trento	30,6	32,4	66,7	31,3	14	72	49,7	15,9	77,6
TO	Torino	64,7	61,6	68,7	32,1	10,8	67,8	48,7	18,4	85,4
TP	Trapani	46,6	38,3	63,2	19,3	6,3	52,4	34	21,5	81,3
TR	Terni	68,4	62,7	51,8	33,6	8,3	69,5	50	16	70,8
TS	Trieste	65,3	63,2	81,00	39,7	16,5	74,6	52,3	14	88,3
TV	Treviso	67,7	67,6	42,30	24,5	9	60,9	50,1	13,5	80,5
UD	Udine	69,9	69,2	50,90	32,1	10,7	72,1	52,3	14	88,3
VA	Varese	69,3	65,7	37,10	32,4	8,5	66,7	51	16,5	87
VC	Vercelli	59,6	53,3	52,90	25,1	9,5	58	48,7	18,4	85,4
VCO	Verbano-Cusio-Ossola	66,7	61,9	22,00	26,3	6,2	57,2	48,7	18,4	85,4
VE	Venezia	65	62,7	54,80	31,2	11,6	66,4	50,1	13,5	80,5
VI	Vicenza	68,9	68,6	45,80	32,1	10	65,7	50,1	13,5	80,5

CODE	PROVINCE	ALP	ANC	FNC	CGT	PCE	HSD	BDS	SDY	IU
VR	Verona	66,5	66,2	56,70	33	8,2	70,7	50,1	13,5	80,5
VT	Viterbo	62,9	56,6	34,00	25,2	8,3	63,1	52,9	16,7	87,1
VV	Vibo Valentia	49,2	35,9	25,70	27,5	19,8	56,7	33,8	15,3	88,3

Italian regions dataset

Region	ALP	ANC	FNC	CGT	PCE	HSD	BDS	SDY	IU
Abruzzo	64,4	56,9	52,5	28,9	10,6	68,4	43,1	16,4	84,2
Basilicata	44,7	51,1	37,5	25,1	8,8	63	36,1	12,4	83,7
Bolzano	60,6	58,5	22,2	25,7	14,6	69,5	47,6	17,6	85,8
Calabria	67,5	37,8	33,9	24,3	8,5	56,6	33,8	15,3	88,3
Campania	72,5	41,8	63,5	23,6	7,2	53,8	34,2	8,4	87,4
Emilia-Romagna	67,8	63,1	52,5	32,2	11,9	68,1	51,2	3,1	86,6
Friuli-Venezia Giulia	68,2	66,5	52	31,2	11,8	71,2	52,3	14	88,3
Lazio	63,6	56,5	67,9	35,6	11,8	72,1	52,9	16,7	87,1
Liguria	61,9	57,3	51,9	30,3	11,4	69,6	49,1	18,5	88,3
Lombardia	59,4	65,3	53,8	31,8	9,4	65,4	51	16,5	87
Marche	59,4	65,7	46,5	33,5	10	65,9	46	13,8	85,9
Molise	60	55	62,7	32,1	10	63,1	37,7	17	85,8
Piemonte	73,1	61,1	54,8	28,3	9,4	64	48,7	18,4	85,4
Puglia	61,3	49,7	46,5	22,1	7,2	52,5	38,5	18,2	84,8
Sardegna	66,9	44,7	36,4	25	12,2	54,6	45,4	19,7	82,2
Sicilia	67,3	38,3	59,5	19,4	6,3	52,4	34	21,5	81,3
Toscana	68,5	62,1	50,1	29,7	10,6	65,5	49,8	15,9	77,7
Trento	52,3	69,4	66,7	31,3	14	72	51,7	18,3	79,3
Umbria	63,3	65,1	51	33,1	11,2	71,5	50	16	70,8
Valle d'Aosta	53,9	69,6	39,7	30,2	10,2	62,1	50,3	13,5	77,5
Veneto	59	66,8	49,9	31,2	10,1	65,6	50,1	13,5	80,5

Cluster division of the provinces

CODE	PROVINCE	CLUSTER
AG	Agrigento	1
BR	Brindisi	1
BZ	Bolzano	1
CR	Crotone	1
CS	Cosenza	1
EN	Enna	1
FG	Foggia	1
NU	Nuoro	1
OR	Oristano	1
RC	Reggio di Calabria	1
SR	Siracusa	1
SS	Sassari	1
TA	Taranto	1
VV	Vibo Valentia	1
CL	Caltanissetta	2
CT	Catania	2
ME	Messina	2
NA	Napoli	2
PA	Palermo	2
RG	Ragusa	2
TN	Trento	2
TP	Trapani	2
AQ	L'Aquila	3
AV	Avellino	3
BA	Bari	3
BAT	Barletta-Andria-Trani	3
BI	Biella	3
BN	Benevento	3
CB	Campobasso	3
CE	Caserta	3
CH	Chieti	3
CM	Cremona	3
CZ	Catanzaro	3
GR	Grosseto	3
IS	Isernia	3
MS	Massa-Carrara	3
MT	Matera	3
PZ	Potenza	3
SA	Salerno	3
VC	Vercelli	3
AL	Alessandria	4
AO	Aosta	4
AR	Arezzo	4

CODE	PROVINCE	CLUSTER
AT	Asti	4
BG	Bergamo	4
BL	Belluno	4
BS	Brescia	4
CN	Cuneo	4
CO	Como	4
FM	Fermo	4
FR	Frosinone	4
GO	Gorizia	4
IM	Imperia	4
LA	Latina	4
LC	Lecco	4
LE	Lecce	4
LI	Livorno	4
LO	Lodi	4
LU	Lucca	4
MC	Macerata	4
NO	Novara	4
PI	Pisa	4
PN	Pordenone	4
PS	Pesaro e Urbino	4
PT	Pistoia	4
PV	Pavia	4
RI	Rieti	4
RO	Rovigo	4
SI	Siena	4
SP	La Spezia	4
SV	Savona	4
TE	Teramo	4
TV	Treviso	4
VA	Varese	4
VCO	Verbano-Cusio-Ossola	4
VI	Vicenza	4
VT	Viterbo	4
CA	Cagliari	5
GE	Genova	5
MI	Milano	5
MN	Mantova	5
PE	Pescara	5
PO	Prato	5
RM	Roma	5
TO	Torino	5
TS	Trieste	5
AN	Ancona	6

CODE	PROVINCE	CLUSTER
AP	Ascoli Piceno	6
BO	Bologna	6
FE	Ferrara	6
FI	Firenze	6
FO	Forlì-Cesena	6
MB	Monza e della Brianza	6
MO	Modena	6
PC	Piacenza	6
PD	Padova	6
PG	Perugia	6
PR	Parma	6
RA	Ravenna	6
RE	Reggio nell'Emilia	6
RN	Rimini	6
SO	Sondrio	6
TR	Terni	6
UD	Udine	6
VE	Venezia	6
VR	Verona	6

Appendix 2: main R code[3]

```
library(readxl)
Italy <- read_excel("Desktop/INDICATORI.xlsx", sheet = "#INDICATORI")
View(Italy)
Italy= Italy [c(1:11)]
rownames(Italy)= Italy $CODICE
Italy = Italy2[-c(1)]
rownames(Italy 2)= Italy$CODICE
dist_E2 <- dist(Italy2, method="euclidean")
Italy_w <- hclust(dist_E2, method = "ward.D")
plot(Italy_w)
grp <- cutree(Italy_w, k = 2)
plot(Italy_w, cex = 0.6)
rect.hclust(Italy_w, k = 2, border = 2:5)
#Italy
library(parsec)
prf <- pop2prof(Italy2, labtype="rownames")
z <- getzeta(prf)
plot(z)
avr_IT <- average_ranks(z)
plot(avr_IT)
P <-MRP (z,method="approx")
v <-abs(svd(P)$v[,1])
head(v)
library(parsec)
#Regions
prfRG <- pop2prof(RG, labtype="rownames")
zRG <- getzeta(prfRG)
plot(zRG)
avr_RG <- average_ranks(zRG)
plot(avr_RG)
P_RG <-MRP (zRG,method="exact")
vRG <-abs(svd(P_RG)$v[,1])
RG_r=cbind.data.frame(RG,vRG)
rownames(RG_r)=RG$PROVINCIA
RG_r=RG_r[-c(1)]

#Nord-ovest
rownames(Cluster_1)=Cluster_1$CODICE
```

[3] The R code was reported only partially as the code repeats itself for each of the zone, also known as NUTS 1.

```
Cluster_3=Cluster_1[-c(1)]
rownames(Cluster_3)=Cluster_1$CODICE
#Assoluto
library(parsec)
prf <- pop2prof(Cluster_3, labtype="rownames")
z1 <- getzeta(prf)
plot(z1)
avr_NO <- average_ranks(z1)
plot(avr_NO)
#Ranking#
P1 <-MRP (z1,method="approx")
v1 <-abs(svd(P1)$v[,1])
head(v1)
NO_r=cbind.data.frame(Cluster_1, v1)
rownames(NO_r)=Cluster_1$CODICE
NO_r=NO_r[-c(1)]
```