Not everything is about technology. Investigating Green Innovation among clusters

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Abstract

This paper explores the role of clusters in fostering Green Innovation and identifies factors that promote the diffusion of these practices. While clusters have been recognized as important for understanding sustainable transitions, the literature lacks large datasets and statistical analyses to map out and extend comparisons at the cluster level. To fill this gap, the study establishes a ranking of the most prominent clusters in terms of Green Innovation by analyzing the topics of the websites of 31,833 companies and identifying similarities between Green Innovation. Contrary to previous patent-based studies, the ranking integrates a more nuanced definition of Green Innovation based on topic modelling. To identify causal patterns that might explain the emergence Green Innovation among clusters, the study conducted a fuzzy set qualitative comparative analysis (fsQCA) based on the level of agglomeration of the cluster (LQ-Index), the external knowledge stock, (patent count per capita), and institutional pressure, detailed in the three dimensions of Social Progress Index (Basic Human Needs, Foundations of Wellbeing and Opportunity). The study contributes to the literature on Green Innovation by providing a more comprehensive analysis of clusters' role in fostering sustainable practices and identifying factors that facilitate Green Innovation diffusion among clusters.

Keywords: Green Innovation, clusters, cluster mapping, social progress, Italy

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1. Introduction

Clusters, defined as "geographically concentrations of interconnected companies and institutions in a particular field" (Porter, 1998), are essential in comprehending how specific locations can transition from traditional practices to new sustainable ones (Bridge et al., 2013; Porter and Kramer, 2011). the issue of Green Innovation has received significant attention in academic research and among companies and policymakers in response to pressing global economic and environmental challenges (Takalo et al., 2021).

Over the years, several factors have been identified to affect the diffusion of Green Innovation in clusters, such as knowledge transfer and sharing, also known as knowledge spillover (Ter Wal and Boschma, 2011; Balland, 2012; Giuliani, 2013). In addition, the literature has highlighted the importance of institutional pressures in fostering Green Innovation (Porter and Vander Linde, 1995; Chen et al., 2018; Cohen and Tubb, 2018;).

Despite the evidence of clusters being conducive to Green Innovation, most contributions in this field have been based on case studies, interviews, and firm-level surveys (Bellandi, 2021; Takalo et al., 2021). Consequently, only a few recent studies have considered a systematic measurement approach based on patent data in Green Innovation (Messeni Petruzzelli et al., 2011; Du et al., 2021; Liu et al., 2022). Furthermore, prior research has suggested that relying solely on patent data to study Green Innovation may result in an incomplete understanding (Martínez-Ros, 2019), as the economic significance of patents varies across industries (Laursen & Salter, 2004).

The primary objective of this study is to assess the divergences in Green Innovation levels among clusters and pinpoint the underlying factors that foster the dissemination of Green Innovation within these clusters. To accomplish this goal, we developed a procedure to identify the most prominent clusters in Green Innovation. Unlike previous studies solely relying on patents, our ranking incorporates a more nuanced definition of Green Innovation through topic modelling. We established our ranking by analyzing the websites of 33.557 companies constituting the 200 traded clusters in Lombardy, Italy's most prosperous region (NUTS-2). We used the Hierachical Latent Dirichlet Allocation (HLDA) text mining method to identify the prevalence of Green Innovation topics.

Subsequently, we performed a fsQCA to uncover potential causal relationships that could clarify the emergence of Green Innovation-focused clusters. The factors evaluated were based on a literature review and included: cluster agglomeration level (measured by the LQ-Index) and external knowledge stock (patent-based). As a proxy for institutional pressure, we measured the current state of social progress, detailing the dimensions of the Social Progress Index, which include basic human needs, foundations of wellbeing, and opportunity.

Our findings show that Green Innovation activity is cluster-specific, showing significant variation in Green Innovation that goes beyond the context- or industry-wide level. Moreover, we highlight three alternative pathways highlighting the role of social progress in creating institutional pressure and the role of opportunity dimensions for successfully exploiting a high level of external knowledge stock. Findings also suggest implications for theory and practice. Compared to similar work in Green Innovation, our study is the first to introduce a measurement based on firms' websites. Our study might inform cluster-based green transformation initiatives based on the solutions provided by focusing on the closest factors leading to green innovation.

The paper proceeds as follows. We begin by reviewing the literature on Green Innovation and clusters. This is followed by a methodological section, illustrated by research design, data collection, and data analysis. Next, we introduce our results and discuss our findings. We conclude by providing final reflections, contributions, limitations, and further research opportunities.

2. Literature review

2.1. Green Innovation and cluster

Climate change, extreme weather events, droughts, wildfires, and other environmental disasters are examples of impacts that threaten the future of humanity. These challenges call for the help of different actors to find answers. From clean energy to health treatments, innovative firms translate scientific knowledge into actionable solutions that can reach a global audience, such as new products, services, processes, business models, technology, and design, leading specific locations to transition from traditional practices to new sustainable ones (Bridge et al., 2013; Porter and Kramer, 2011).

Green Innovation is an essential tool to help companies achieve environmental sustainability and sustain competitive advantage (Chu et al., 2019, Padilla-Lozano and Collazzo, 2022). It improves economic performance while breaking existing open arrangements and contributing to societal change (Geels et al., 2017). Green Innovation is "a process that contributes to the creation of new products and technologies with the aim of reducing environmental risks, like pollution and negative consequences of resource exploitation" (Castellacci and Lie, 2017). Two dimensions have emerged in literature to catch the different aspects of Green Innovation: product innovation and process innovation. Green product innovation is applying innovative ideas in designing, manufacturing and communicating new products (Kam-Sing Wong, 2012), while green process innovation is related to energy saving, waste recycling, pollution prevention, reducing raw material consumption, and non-toxicity in production processes (Chen et al., 2006).

Several factors have been identified to affect the diffusion of Green Innovation among firms, with a prominent share of studies highlighting the role of knowledge transfer and sharing. Knowledge is transferred both informally while involving suppliers, clients, and competitors (i.e. knowledge spillover) (Ter Wal and Boschma, 2011; Balland, 2012; Giuliani, 2013), but also in networks involving formal knowledge such as universities and scientific articles and informal (Arita et al. 2006; Malecki et al., 2010). In addition, the literature has highlighted the importance of institutional pressure, such as a factor in fostering Green Innovation (Porter and Vander Linde, 1995; Chen et al., 2018; Cohen and Tubb, 2018). Firms must comply with normative pressure from external stakeholders such as customers, investors, communities, industry associations and society at large, as well as the laws and regulations of the government (Berrone et al., 2013).

Green Innovation is complex and multidisciplinary (Roscoe et al., 2016; Barbieri et al., 2020). It requires a highly heterogeneous combination of resources and competencies (Zeppini and van den Bergh, 2011) spanning various engineering fields and related sectors. For these reasons, clusters have been recognized in the literature as suitable environments for developing and implementing Green Innovations (De Gouvea and Kassicieh, 2012; Cai and Li, 2018) thanks to their intrinsic collaboration and networking nature (Cainelli et al., 2012; Mazzoni, 2020). Clusters, i.e. geographically co-located producers, suppliers, service providers, research laboratories, educational institutions, and other institutions in a given economic field, enable higher levels of productivity and innovation (Porter, 2008; Delgado et al., 2014). Moreover, regarding institutional pressure, clustered firms are more likely to influence each other and simultaneously pursue environmental innovation by aligning their strategy and competitive agendas toward shared challenges (Mazzanti and Zoboli, 2009). These are the effects of Institutional adjustment in a location, where it gradually increases the

isomorphic pressure with the cluster specialization and adds to the cluster's performance (Maskell and Malmberg, 2007).

Despite the topic's popularity, most contributions to Green Innovation are based on case studies, interviews, and firm-level surveys (Bellandi, 2021; Takalo et al., 2021). Indeed, there is a tendency among green researchers to use data from small samples (Jahan Khan et al., 2021). Only a few recent studies have considered a systematic measurement approach based on patent data in Green Innovation (Messeni Petruzzelli et al., 2011; Du et al., 2021; Liu et al., 2022). Furthermore, prior research has suggested that relying solely on patent data to study Green Innovation may result in an incomplete understanding (Martínez-Ros, 2019), as the economic significance of patents varies across industries (Laursen & Salter, 2004). The lack of large datasets, statistical analysis, and the focus on patent activity led to the lack of extended comparisons in studying Green Innovation.

Moreover, although the primary focus of corporate practices towards more "green solutions" has been on technological innovations, some organizations have broadened the scope to strategic and organizational levels, such as with new business models (i.e. Circular Business Model Innovation) (Tseng et al., 2013; Bocken et al., 2016; Linder and Williander, 2017). Indeed, businesses are increasingly proactive in practising new initiatives for addressing environmental benefits such as reducing emissions, pollution, and waste(Paramati et al., 2020),y reconceiving products, redefining the value chain, and improving their local business environment (Porter and Kramer, 2011). Finally, implementing green technological innovations alone cannot create incremental change sufficiently to achieve decoupling (i.e. reduction of energy and material consumption and increasing economic growth) (Henriksen et al., 2012). As a result, the connection between clusters and Green Innovations remains underinvestigated. Thus, this paper aims to explore Green Innovation in clusters by focusing on the following two research questions:

RQ1. "What is the level of Green Innovation among clusters?"

RQ2. "Which factors foster Green Innovation adoption within clusters?"

The primary objective of this study is to assess the discrepancies in Green Innovation levels among clusters and identify the underlying factors that foster Green Innovation within these clusters. To accomplish this goal, we developed a score to identify the most prominent clusters in terms of Green Innovation. Unlike previous studies solely relying on patents, our ranking incorporates a more nuanced definition of Green Innovation based on text-mining techniques (i.e. topic modelling).

3. Method

3.1. Research design

The methodological approach adopted in this study can be divided into two stages, corresponding to the two research questions. To answer the first one, we establish a Green Innovation score based on the prominence of Green Innovation topics along the company's websites within a cluster. We established our ranking by analyzing the websites of 33.557 companies constituting the 200 traded clusters in Lombardy, a region (NUTS-2) of Italy, the first Italian region in terms of GDP, part of the "Four Motors for Europe". We later used the Hierarchical Dirichlet allocation (HDA) text mining method (Wang et al., 2011) to compute the score.

Textual unstructured data is quickly growing in relevance for research on innovation. The recent development in text mining techniques allows researchers to efficiently explore large-scale collections of texts (Antons, David et al., 2020). For example, text-mining has been used by innovation scholars, such for profiling inventors (Moehrle et al., 2005) for technology forecasting based on analyses of the text in patents (Lee et al., 2008a; Choi et al., 2013), and literature review (e.g., Antons et al., 2016). Text mining has also been employed in location-based studies; for example, Tiba et al. (2021) used a topic modelling approach to rank the sustainability orientation of 28 entrepreneurial ecosystems.

Websites are an essential medium for companies to inform the larger audience about their products, services, values, initiatives and missions, communicating to potential customers, suppliers, investors, and employees. Firms invest and communicate their Green Innovations initiatives to exploit opportunities by positioning themselves as eco-friendly businesses (Chen et al., 2006; Kam-Sing Wong, 2012). However, there is the possibility that companies engage in greenwashing (Lyon and Montgomery, 2015), which involves exaggerating a firm's environmental practices in an overly optimistic light. Nevertheless, we are aware of the possibility of this opportunistic behaviour, but since our level of analysis is the entire cluster, we have no reason to believe that the share of enterprises that engage in greenwashing differs significantly.

In the second part of this study, we performed a fsQCA (Ragin, 2008) to uncover potential relationships that could highlight the emergence of Green Innovation clusters. The factors evaluated were based on a literature review and included in this study: as for the agglomeration level, we used the location quotient, as for external knowledge, we computed the per capita patent count, and for institutional pressure, the Social Progress Index – SPI.

Location quotients are among the most common methods to identify specialization because they can capture spatial agglomeration independently of the size of the place (Von Hofe and Chen, 2006). With a location quotient (LQ) greater than 1, a cluster has reached a critical mass, benefiting from positive externalities and becoming meaningful in that territory's economic activity (Ketels and Protsiv, 2017).

Knowledge production processes are localized, and knowledge spillovers require proximity to several measures beyond the spatial dimension (Feldman & Kogler, 2010; Boschma, 2005). Location plays a prominent role since scientists and inventors create and diffuse knowledge through organizations and entities with physical footprints. Prior studies have considered knowledge stock as the number of patents or accumulated number of patents in a

given location (Colombelli & Quatraro, 2018, 2019; Corradini, 2019; Giudici et al., 2019; Qian & Jung, 2017).

Social progress refers to a society's ability to meet each citizen's basic needs and create conditions for each individual to achieve their potential (Stern and Epner, 2019). Social progress is inherently multidimensional and complex, requiring indicators covering its dimensions (Estes, 2019; Jitmaneeroj, 2017). In 2013, Professor Michael Porter (Harvard) and Scott Stern (MIT) collaborated to develop and disseminate a new concept called the Social Progress Index (SPI) through the non-governmental association Social Progress Imperative (Porter et. al, 2014). The SPI has since been adopted in several countries and subnational territories worldwide. While the SPI does not directly measure institutional pressure, it includes indicators related to institutional quality, such as the effectiveness of the rule of law, the level of corruption, and the strength of democratic institutions. These indicators can be used as proxies for institutional pressure, as they capture the degree to which institutions can provide an enabling environment for individuals and communities to thrive. Moreover, the SPI includes indicators that capture the social outcomes of institutional pressure, such as access to education, health care, and affordable housing.

3.2. Data collection

The empirical field chosen is the Italian cluster landscape. Data collection on Italian clusters at the provincial level (NUTS-3) in the Lombardy region relied on the "Italian cluster mapping project" (Italia Compete, 2020), which was launched in 2020 and developed based on the methodology introduced by Delgado, Porter, and Stern (2016). The three authors operationalized the concept of clusters by creating a new algorithm aimed at defining groups of closely related industries (identified with six-digit NAICS codes) grounded in the cluster's conceptual framework (Porter, 1990; 1998; Delgado, Porter and Stern, 2014). The algorithm groups narrowly defined and mutually exclusive industries that show significant inter-industry linkages based on input-output measures, labour occupations, and the co-location patterns of employment and establishments. The methodology distinguished between 51 traded clusters and 16 local clusters. Traded clusters are groups of geographically concentrated industries that serve markets beyond the country and region in which they are located. Local clusters are more dispersed groups of industries that, in contrast, serve the local market.

We focused our analysis only on Traded Clusters surpassing a threshold of employees and establishments., adopting a minimum cutoff size of 250 employees and 10 establishments (i.e., number of companies) as seen in (Lazzeretti et al. 2014). According to Delgado, Porter, and Stern (2014), the Traded clusters are the engine of a regional economy, showing higher productivity and productivity growth than the regional average. This selection resulted in 200 Clusters among the 11 Lombardy provinces (NUTS-3).

Data on the companies participating in the selected cluster (i.e. registered name, administrative information, NACE rev2 industrial classification code, trading address and the website and value of production) are retrieved from the AIDA database provided by Bureau van Dijk.

We downloaded firms' websites and the subpages listed in the AIDA database to obtain their text content. We ultimately obtained textual information on 22.502 companies from the

original 33.557 with a coverage of the 67,06%, given that several websites did not contain downloadable in Italia. The number of firms identified in each cluster and the relative coverage rate are shown in Table 1. Clusters with a relatively low number of firms (less than 50) were excluded due to not being sufficiently representative.

Table 1 – Number of firms and coverage of data collection

Industry	No. of Firms	No. of Firms website information retrieved	Coverage
Distribution and Electronic Commerce	6942	5114	73.67%
Business Services	6078	3224	53.04%
Metalworking Technology	4135	2560	61.91%
Production Technology and Heavy Machinery	2230	1780	79.82%
Marketing, Design, and Publishing	1523	1194	78.40%
Transportation and Logistics	1276	919	72.02%
Hospitality and Tourism	1105	883	79.91%
Plastics	855	675	78.95%
Textile Manufacturing	889	662	74.47%
Lighting and Electrical Equipment	712	558	78.37%
Downstream Metal Products	650	494	76.00%
Food Processing and Manufacturing	890	418	46.97%
Downstream Chemical Products	902	416	46.12%
Information Technology and Analytical Instruments	792	350	44.19%
Education and Knowledge Creation	408	335	82.11%
Printing Services	433	315	72.75%
Furniture	324	265	81.79%
Automotive	351	260	74.07%
Wood Products	345	259	75.07%
Construction Products and Services	314	237	75.48%
Vulcanized and Fired Materials	280	213	76.07%
Paper and Packaging	244	178	72.95%
Medical Devices	200	160	80.00%
Financial Services	205	157	76.59%
Recreational and Small Electric Goods	198	151	76.26%
Apparel	194	143	73.71%
Video Production and Distribution	150	116	77.33%
Environmental Services	134	103	76.87%
Communications Equipment and Services	110	87	79.09%
Upstream Metal Manufacturing	94	71	75.53%
Performing Arts	95	69	72.63%
Biopharmaceuticals	89	68	76.40%
Agricultural Inputs and Services	83	68	81.93%
Insurance Services	47	Excluded (less than 50 firms)	
Footwear	46		
Leather and Related Products	33		
Water Transportation	29		
Livestock Processing	31		
Upstream Chemical Products	31		
Electric Power Generation and Transmission	32		
Jewellery and Precious Metals	26		
Oil and Gas Production and Transportation	26		
Music and Sound Recording	26		
Total	*33557*	*22502*	*67.06%*

As for the factors possibly showing a causal relationship with Green Innovation, LQ Index is computed from the employment data from ISTAT ASIA UL (2020), patents per capita from UIBM (Italian patent office) from 2000 to 2020. As for SPI, Table A1 details the variables and sources included. 62 variables make up the final index. Several data sources were used for the construction of the index, including:: Indicatori Health for All (2020), Indicatori Benessere e Sostenibilità (2022), Acqua (2020), Scenari Immobiliari (2020), ICityRanking (2022), Legambiente (2022), ISPRA (2022), Institutional Quality index (Nifo and Vecchione, 2014) and Agcom (2020).

3.3. Data cleaning

The Content Extractor

Although texts are ubiquitous on the Web, extracting information from web pages can be complicated. Web pages are often cluttered with additional features around the main textual content, such as navigation panels, pop-ups, cookie policies, and advertisements (i..e boilerplate text). These noisy parts tend to affect the performances of NLP tasks negatively.

The extraction focuses on the main content, usually displayed centrally, without the header, footer, left, or right filler. This task is also known as web scraping, boilerplate removal, DOM-based content extraction, main content identification, or web page cleaning.

As for the content extraction, we relied on Trafilatura 1.2.2, a Python package and command-line tool designed to gather information from the Web (Barbaresi, A., 2021). It includes discovery, extraction and text-processing components. Trafilatura has been extensively evaluated against other content extractors, resulting in the best score in terms of precision, an essential metric for topic modelling (Blei et al., 2003).

Stemming and Lemmatization

Texts obtained from web pages were preprocessed by removing numbers, punctuation and common stop words that frequently occur in texts without contributing significant meaning (such as the Italian equivalent to English "the", 'and', "a", "an", and "some"). The next step involves stemming and Lemmatization, two techniques used in natural language processing (NLP) to normalize words to their base form. Although both techniques aim to reduce words to their base form, their approach differs.

Stemming is removing the suffixes from a word to obtain its base form. Stemming algorithms use simple rules to remove suffixes from the end of words, such as -ing, -s, -es, etc. The resulting base form may not always be valid in the language but reduces the word to a common base form. For example, the stem of the words "running," "runner," and "runs" is "run". On the other hand, Lemmatization is the process of reducing a word to its base or dictionary form, known as a lemma. Unlike stemming, Lemmatization considers the word's context and its part of speech. For example, the lemma of the word "better" is "good," while the lemma of the word "am" is "be." Lemmatization algorithms use language-specific morphological analysis to determine the lemma of a word. Lemmatization refers to deriving the root words from the inflected words. A lemma is the dictionary form of the word(s) in the field of morphology or lexicography.

As for Stemming, we relied on the Snowball stemming algorithm (Porter, 2001). The Snowball Italian stemmer is an adaptation of the original English version and thus restrains itself from suffix-stripping. We relied on its implementation in the library "Natural Language Toolkit" - NLTK (Steven, 2006).nAs for elimination, we used TreeTagger (Schmid, 1994). TreeTagger is available in over 25 languages, Italian included. Finally, we removed all words not appearing on at least 15 websites (Griffiths and Steyvers, 2004).

3.4. Data analysis

Topic Modelling and hierarchical Dirichlet process

Topic models are a family of computer programs that extract topics from texts. A topic is defined as a list of words that occur in statistically meaningful ways. The hierarchical Dirichlet process (HDP) is a Bayesian nonparametric model widely applied in probabilistic topic modelling, where documents are distributions of terms that reflect recurring patterns (or "topics") (Wang and Blei, 2011). Unlike its finite counterpart, latent Dirichlet allocation (LDA) (Blei, 2003), the HDP topic model infers the number of topics from the data. We relied on the hdpmodel implemented in the library GENSIM 4.3.0 (Python). We used HDP with a Term Frequency-inverse Document Frequency (TF-IDF). This procedure identifies whether specific words appear uniformly and frequently in most texts (i.e. most common words) and thus give little information about their topic (Salton and McGill, 1983).

Scoring Green Innovation

Green Innovation involves a wide range of efforts to improve environmental sustainability, and, as stated before, this paper broadly views Green Innovation, considering any innovations that reduce the negative environmental impact of firms. Even with this broad definition, only a subset of the topics from the downloaded websites is relevant to Green Innovation. When determining which topics are relevant to Green Innovation, we relied on the definition Castellacci and Lie (2017) adopted in creating a taxonomy for green innovators. In line with Kemp and Pearson (2007) works, the authors investigated green product and process innovation as the environmental benefits that firms have experienced by reducing energy use, raw material use, CO2 footprint, oil, water, noise or air pollution and the recycling of waste, water and substitution of polluting/hazardous materials.

Moreover, we also considered that Green Innovation practices might differ among different industries. For example, manufacturing firms mitigate adverse environmental impacts through renewable energy (Burki and Dahlstrom, 2017; Kumar and Rahman, 2015), producing the lowest amount of waste and emission with the solution in the production process (Roy and Khastagir, 2016). The same cannot be the case with services (i.e. Hospitality and Tourism), where the focus is more on environmentally sustainable practices (Wang et al., 2022), such as using fewer materials in the design of products (Gürlek and Tuna, 2018) or using applications to reduce the consumption of electricity, water (Albort-Morant et al., 2017; Singh, Del Giudice, et al., 2020), and using efficient heating systems (del Rosario Reyes-Santiago et al., 2019).

Given the importance of taking into consideration the industry when identifying the green topics, we adopted an industry step-wise approach, categorizing the topics for all the clusters within the same industry, taking into consideration keywords such as energy, recycling, reducing, resources, sustainability, environment, and consumption. Moreover, the websites with the highest similarities have been manually checked for each resulting topic.

Table A2 details the list of topics found for Green Innovation within each industry that constitute the sets of the topic of Green Innovation, while Figure 1 is the word cloud of the topics, displaying the most frequent word with the largest dimension. For each step, the Topic coherence value is reported. The score refers to the semantic similarity scores between high-

probability words within a topic and is used to evaluate the topic modelling algorithm (Mimno et al., 2011).

Figure 1 - Wordcloud of Green Innovation topics words

After defining the topics of Green Innovation, we evaluated each company website against the presence of these topics. A threshold of 10% was set (Krestel et al., 2009), so all companies with websites with at least 10% of their text dedicated to one of the relevant Green Innovation topics were counted as Green Innovation firms. The Green Innovation score for each cluster was then calculated by considering the value of the production of Green Innovation companies in that cluster by the total value of the production of the cluster.

FsQCA

The Qualitative Comparative Analysis (QCA) method emerged in the late 1980s Ragin (1987). QCA offers an innovative approach, particularly in situations with multilevel explanations and influences (Woodside, 2013). Drawing on a configurational understanding of how a combination of causes leads to the same results, QCA studies are designed to combine techniques from qualitative and quantitative approaches, making these studies inherently mixed technique applications. Qualitative inductive reasoning with data being analyzed “by case” and not “by variable” (Ragin, 2000) is combined with quantitative empirical testing as sufficient and necessary conditions identify outcomes through statistical methods (Longest & Vaisey, 2008; Ordanini et al., 2014).

As a destination is usually reached through different routes, an outcome may occur by different combinations of antecedent conditions. This is the principle of equifinality, which is the premise that multiple combinations of antecedent conditions are equally effective in causing an outcome (Von Bertalanffy, 1968; Fiss, 2007). Numerous factors can influence the diffusion of Green Innovation practices within clusters, with different combinations and levels. This means that not all factors (or antecedents) are needed to explain a particular outcome (ie. Green innovation), and some combined can likely be sufficient to explain high adoption or usage. Ragin (2008) overcomes the crisp set (i.e. dichotomous variables based) QCA (csQCA) method by using fuzzy set theory and Boolean logic, giving rise to fuzzy set Qualitative Comparative Analysis (fsQCA). This modification of conventional QCA allows continuous or interval-scale variables, which first require calibration to transform them into

fuzzy categories or conditions. This study uses the statistical software package fsQCA 4.0 for its analysis (Ragin, 2022).

Factors

As for agglomeration, the location quotient (LQ) given from the share of employment in a cluster in a province over the share of employees of a given cluster at the national level. As for external knowledge stock, we computed the summarization of patents from 2000 to 2020 in a given province, divided by the average number of establishment in that province in the last 10 years. As for the Social progress index, The instructions available in the methodology of SPI (Stern, Scott, et al., 2014) were followed for data processing. Before constructing the index, the indicators expressing a result of less social progress must be inverted so that a high indicator value corresponds to more significant social progress. After verifying the directionality, normal standardization is applied to all indicators. The last step before data aggregation is to scale the normalized indicators with a "utopian/dystopian" scenario procedure. In this way, the indicators will have a score ranging from 0 to 100, where 0 represents a "dystopian" scenario and 100 represents a "utopian" one. The dystopian scenario is given by the minimum indicator level observed in the territories under analysis from which the standard deviation is subtracted. Similarly, the utopian scenario is given by the maximum level of the observed indicator to which the standard deviation is added. The indicators are aggregated into components according to weights determined by the PCFA procedure. The components are aggregated into three dimensions with equal weight.

Calibration

The present study's outcome is 'Green Innovation' (GREEN_INNO). The antecedents examined, following the calibration procedure, are a series of characteristics of a cluster: Location quotient (LQ), available knowledge stock (KNW) and the three dimensions of social progress index: 1) basic humans needs (BHN), the foundation of wellbeing (FOW) and 3) opportunity (OPP). Descriptive statistics of the factors included in the FsQCA are provided in Table 2.

Table 2 – Factors descriptive statics.

Variable	Mean	Std. Dev.	Minimum	Maximum
LQ	1.60	1.27	0.22	6.97
BHN	68.65	1.90	63.16	72.18
FOW	51.32	3.00	42.41	56.49
OPP	55.96	3.06	50.42	61.49
KNW	148.34	254.05	0.93	670.35
GREEN_INNO	0.12	0.18	0.00	1.00

The calibration used the "direct method" by Ragin (2008), which implies interval transformation. The percentiles allow the calibration of any measure regardless of its original values. In detail, we compute the 95%, 50%, and 5% of each factor as the three thresholds for the calibration in fsQCA software.

4. Findings and discussion

We first scored the Green Innovation at clusters and industry-wide levels (Tables 2 and 3). Green Innovation shows a concentration pattern that ranges differently among Lombardy's provinces, with Cremona scoring at 21.04% of the value of production of firms in traded cluster involved in Green Innovation and Lodi at 0.12%.

Table 2. Green Innovation score among Lombardy provinces (NUTS-3).

Province	GI score
Cremona	21.04%
Brescia	12.46%
Pavia	12.39%
Milano	11.55%
Bergamo	11.00%
Grand Total	11.00%
Varese	10.38%
Mantova	7.84%
Monza e della Brianza	7.79%
Como	7.42%
Sondrio	2.98%
Lecco	2.01%
Lodi	0.12%

A more widespread situation occurs among industries (i.e. when applying traded cluster definition without geographical boundaries), where Environmental Services score at 96,27%. We expect this industry to be particularly active in Green Innovation, given that this industry contains establishments primarily engaged in the collection, treatment, processing, and disposal of waste, mainly active in recycling. Three industries (i.e., Marketing, Design, and Publishing, Agricultural Inputs and Services and Video Production and Distribution) did not have any topic related to Green Innovation. The lowest non-zero score is achieved by Communications Equipment and Services, with only the 0.22% of the production value from firms involved in Green Innovation.

Table 3. Green Innovation among Lombardy's industries.

Industry	GI score	
Environmental Services	96.27%	
Food Processing and Manufacturing	40.12%	
Education and Knowledge Creation	37.17%	
Medical Devices	36.19%	
Printing Services	28.22%	
Construction Products and Services	24.79%	
Hospitality and Tourism	23.51%	
Automotive	23.07%	
Recreational and Small Electric Goods	20.30%	
Business Services	16.61%	
Vulcanized and Fired Materials	16.52%	
Information Technology and Analytical Instruments	16.26%	
Downstream Chemical Products	15.69%	
Biopharmaceuticals	14.14%	
Furniture	14.09%	
Textile Manufacturing	12.27%	
Apparel	12.17%	
Grand Total	11.00%	
Wood Products	10.48%	
Paper and Packaging	9.40%	
Distribution and Electronic Commerce	9.39%	
Transportation and Logistics	8.15%	
Plastics	6.31%	
Upstream Metal Manufacturing	5.38%	
Production Technology and Heavy Machinery	4.05%	
Downstream Metal Products	1.32%	
Lighting and Electrical Equipment	1.32%	
Financial Services	1.20%	
Metalworking Technology	0.28%	
Communications Equipment and Services	0.22%	
Marketing, Design, and Publishing	0.00%	*
Agricultural Inputs and Services	0.00%	*
Video Production and Distribution	0.00%	*

**no Green Innovation topics found*

The results show that the level of Green Innovation varies across the province and industry and that the cluster level (combining a particular sector and location) can lead to a better understating of the phenome. In Table 4, it is possible to observe the different levels of current strengths in green technology innovation across Lombardy clusters. From a location-based perspective, even the most virtuous provinces in Green Innovation (i.e. Cremona, Brescia and Pavia) show different levels of green innovation across clusters in their specialization portfolio.

For example, Cremona displays a high level of green specialization in Food Processing and Manufacturing (53,91%), Business services (17,25%) and Transportation and Logistics (12,34%), but a low level of green specialization in Plastics, Metalworking technologies, and Vulcanized and Fired Materials clusters. If we take a sector-wide perspective, the results are similar. For example, If we take Plastics, the score varies from 15.45% in Varese, 4.60% in Milano, and there are differences across regions. Paper and Packaging scored the 16,59% in Bergamo against the 2,60% in Monza and Brianza.

These results suggest that other factors, in addition to the industry- or the location-wide, are at play when explaining the causation of Green Innovation.

Table 4 – Green Innovation scores for Lombardy's traded clusters.

#	Cluster	Province	GI score	#	Cluster	Province	GI score
1	Environmental Services	Bergamo	100.00%	101	Plastics	Bergamo	4.40%
2	Environmental Services	Milano	96.08%	102	Hospitality and Tourism	Como	4.30%
3	Environmental Services	Brescia	94.59%	103	Production Technology and Heavy Machinery	Como	4.22%
4	Construction Products and Services	Como	78.24%	104	Business Services	Pavia	4.22%
5	Food Processing and Manufacturing	Varese	65.73%	105	Business Services	Mantova	4.18%
6	Printing Services	Bergamo	62.88%	106	Wood Products	Mantova	4.15%
7	Apparel	Varese	61.33%	107	Production Technology and Heavy Machinery	Cremona	3.99%
8	Food Processing and Manufacturing	Cremona	53.91%	108	Textile Manufacturing	Milano	3.56%
9	Food Processing and Manufacturing	Pavia	51.49%	109	Education and Knowledge Creation	Monza e della Brianza	3.50%
10	Printing Services	Brescia	50.08%	110	Transportation and Logistics	Mantova	3.15%
11	Construction Products and Services	Brescia	47.22%	111	Production Technology and Heavy Machinery	Milano	3.10%
12	Recreational and Small Electric Goods	Brescia	46.54%	112	Upstream Metal Manufacturing	Como	3.05%
13	Information Technology and Analytical Instruments	Bergamo	44.61%	113	Paper and Packaging	Monza e della Brianza	2.60%
14	Food Processing and Manufacturing	Bergamo	44.20%	114	Information Technology and Analytical Instruments	Monza e della Brianza	2.58%
15	Food Processing and Manufacturing	Brescia	42.88%	115	Transportation and Logistics	Lecco	2.44%
16	Medical Devices	Milano	41.96%	116	Business Services	Sondrio	2.39%
17	Education and Knowledge Creation	Milano	39.29%	117	Downstream Metal Products	Lecco	2.36%

18	Food Processing and Manufacturing	Milano	38.94%
19	Vulcanized and Fired Materials	Bergamo	37.69%
20	Paper and Packaging	Varese	37.33%
21	Construction Products and Services	Monza e della Brianza	37.04%
22	Education and Knowledge Creation	Bergamo	35.95%
23	Transportation and Logistics	Como	35.28%
24	Hospitality and Tourism	Milano	31.57%
25	Printing Services	Monza e della Brianza	30.94%
26	Automotive	Milano	30.87%
27	Automotive	Brescia	29.48%
28	Medical Devices	Bergamo	28.02%
29	Vulcanized and Fired Materials	Brescia	25.72%
30	Textile Manufacturing	Monza e della Brianza	25.35%
31	Food Processing and Manufacturing	Mantova	24.12%
32	Construction Products and Services	Milano	22.10%
33	Wood Products	Milano	22.00%
34	Automotive	Monza e della Brianza	21.85%
35	Printing Services	Varese	21.54%
36	Furniture	Monza e della Brianza	20.56%
37	Vulcanized and Fired Materials	Monza e della Brianza	20.51%
38	Downstream Chemical Products	Monza e della Brianza	19.82%
39	Textile Manufacturing	Como	19.58%
40	Production Technology and Heavy Machinery	Monza e della Brianza	19.50%
41	Education and Knowledge Creation	Brescia	19.13%
42	Medical Devices	Brescia	19.04%
43	Business Services	Milano	18.45%
44	Printing Services	Milano	18.01%
45	Information Technology and Analytical Instruments	Milano	17.98%
46	Transportation and Logistics	Varese	17.96%
47	Downstream Chemical Products	Milano	17.95%
48	Business Services	Cremona	17.25%
49	Wood Products	Brescia	17.14%
118	Information Technology and Analytical Instruments	Brescia	2.33%
119	Lighting and Electrical Equipment	Varese	2.24%
120	Furniture	Brescia	2.21%
121	Upstream Metal Manufacturing	Varese	2.16%
122	Lighting and Electrical Equipment	Milano	1.98%
123	Automotive	Varese	1.94%
124	Furniture	Como	1.92%
125	Hospitality and Tourism	Brescia	1.87%
126	Production Technology and Heavy Machinery	Lecco	1.72%
127	Production Technology and Heavy Machinery	Pavia	1.71%
128	Business Services	Como	1.57%
129	Metalworking Technology	Milano	1.43%
130	Downstream Metal Products	Brescia	1.41%
131	Downstream Chemical Products	Brescia	1.29%
132	Apparel	Milano	1.21%
133	Financial Services	Milano	1.20%
134	Upstream Metal Manufacturing	Bergamo	1.17%
135	Lighting and Electrical Equipment	Lecco	1.16%
136	Production Technology and Heavy Machinery	Bergamo	1.11%
137	Plastics	Pavia	1.07%
138	Downstream Chemical Products	Como	0.89%
139	Lighting and Electrical Equipment	Monza e della Brianza	0.84%
140	Lighting and Electrical Equipment	Brescia	0.82%
141	Production Technology and Heavy Machinery	Varese	0.60%
142	Transportation and Logistics	Brescia	0.46%
143	Plastics	Monza e della Brianza	0.40%
144	Business Services	Lodi	0.34%
145	Metalworking Technology	Monza e della Brianza	0.25%
146	Communications Equipment and Services	Milano	0.22%
147	Metalworking Technology	Lecco	0.20%
148	Distribution and Electronic Commerce	Brescia	0.04%
149	Distribution and	Varese	0.00%

50	Construction Products and Services	Bergamo	16.83%
51	Paper and Packaging	Bergamo	16.59%
52	Downstream Chemical Products	Bergamo	16.06%
53	Transportation and Logistics	Bergamo	15.50%
54	Plastics	Varese	15.45%
55	Business Services	Bergamo	14.88%
56	Food Processing and Manufacturing	Monza e della Brianza	14.62%
57	Biopharmaceuticals	Milano	14.14%
58	Recreational and Small Electric Goods	Bergamo	13.96%
59	Furniture	Bergamo	13.82%
60	Distribution and Electronic Commerce	Milano	13.70%
61	Information Technology and Analytical Instruments	Varese	13.65%
62	Textile Manufacturing	Varese	12.42%
63	Wood Products	Monza e della Brianza	12.39%
64	Transportation and Logistics	Cremona	12.34%
65	Textile Manufacturing	Brescia	12.08%
66	Recreational and Small Electric Goods	Milano	11.62%
67	Vulcanized and Fired Materials	Milano	11.29%
68	Textile Manufacturing	Mantova	10.97%
69	Wood Products	Como	10.72%
70	Downstream Chemical Products	Varese	10.69%
71	Wood Products	Bergamo	10.65%
72	Medical Devices	Varese	10.00%
73	Wood Products	Varese	9.66%
74	Business Services	Lecco	9.58%
75	Furniture	Milano	9.57%
76	Automotive	Bergamo	9.17%
77	Hospitality and Tourism	Bergamo	8.45%
78	Textile Manufacturing	Lecco	8.43%
79	Printing Services	Como	7.98%
80	Transportation and Logistics	Monza e della Brianza	7.89%
81	Textile Manufacturing	Bergamo	7.40%
82	Upstream Metal Manufacturing	Brescia	6.93%
150	Electronic Commerce Downstream Metal Products	Varese	0.00%
151	Hospitality and Tourism	Varese	0.00%
152	Marketing, Design, and Publishing	Varese	0.00%
153	Metalworking Technology	Varese	0.00%
154	Distribution and Electronic Commerce	Sondrio	0.00%
155	Hospitality and Tourism	Sondrio	0.00%
156	Metalworking Technology	Sondrio	0.00%
157	Distribution and Electronic Commerce	Pavia	0.00%
158	Metalworking Technology	Pavia	0.00%
159	Distribution and Electronic Commerce	Monza e della Brianza	0.00%
160	Hospitality and Tourism	Monza e della Brianza	0.00%
161	Marketing, Design, and Publishing	Monza e della Brianza	0.00%
162	Agricultural Inputs and Services	Milano	0.00%
163	Downstream Metal Products	Milano	0.00%
164	Electric Power Generation and Transmission	Milano	0.00%
165	Footwear	Milano	0.00%
166	Insurance Services	Milano	0.00%
167	Jewelry and Precious Metals	Milano	0.00%
168	Leather and Related Products	Milano	0.00%
169	Marketing, Design, and Publishing	Milano	0.00%
170	Music and Sound Recording	Milano	0.00%
171	Oil and Gas Production and Transportation	Milano	0.00%
172	Performing Arts	Milano	0.00%
173	Upstream Chemical Products	Milano	0.00%
174	Video Production and Distribution	Milano	0.00%
175	Water Transportation	Milano	0.00%
176	Distribution and Electronic Commerce	Mantova	0.00%
177	Livestock Processing	Mantova	0.00%
178	Metalworking Technology	Mantova	0.00%
179	Plastics	Mantova	0.00%
180	Distribution and Electronic Commerce	Lodi	0.00%
181	Metalworking Technology	Lodi	0.00%
182	Production Technology and Heavy Machinery	Lodi	0.00%

83	Production Technology and Heavy Machinery	Mantova	6.78%	183	Distribution and Electronic Commerce	Lecco	0.00%
84	Apparel	Bergamo	6.63%	184	Plastics	Lecco	0.00%
85	Plastics	Brescia	6.62%	185	Distribution and Electronic Commerce	Cremona	0.00%
86	Transportation and Logistics	Pavia	6.62%	186	Downstream Chemical Products	Cremona	0.00%
87	Food Processing and Manufacturing	Sondrio	6.55%	187	Metalworking Technology	Cremona	0.00%
88	Apparel	Brescia	6.41%	188	Distribution and Electronic Commerce	Como	0.00%
89	Transportation and Logistics	Milano	6.40%	189	Downstream Metal Products	Como	0.00%
90	Upstream Metal Manufacturing	Monza e della Brianza	6.20%	190	Marketing, Design, and Publishing	Como	0.00%
91	Paper and Packaging	Milano	6.18%	191	Metalworking Technology	Como	0.00%
92	Paper and Packaging	Brescia	6.07%	192	Plastics	Como	0.00%
93	Business Services	Monza e della Brianza	6.06%	193	Agricultural Inputs and Services	Brescia	0.00%
94	Business Services	Brescia	5.34%	194	Marketing, Design, and Publishing	Brescia	0.00%
95	Downstream Metal Products	Monza e della Brianza	5.09%	195	Metalworking Technology	Brescia	0.00%
96	Upstream Metal Manufacturing	Milano	4.80%	196	Distribution and Electronic Commerce	Bergamo	0.00%
97	Business Services	Varese	4.76%	197	Downstream Metal Products	Bergamo	0.00%
98	Production Technology and Heavy Machinery	Brescia	4.74%	198	Lighting and Electrical Equipment	Bergamo	0.00%
99	Plastics	Milano	4.60%	199	Marketing, Design, and Publishing	Bergamo	0.00%
100	Upstream Metal Manufacturing	Lecco	4.41%	200	Metalworking Technology	Bergamo	0.00%

Factors for Green Innovation

The first step of fsQCA involved testing for necessary conditions for a cluster with a high share of Green Innovation by examining consistency values for each causal condition. A causal condition is necessary if its consistency value equals or exceeds 0.90 (Schneider and Wagemann, 2012). Agglomeration (i.e. a critical mass of employment in a given traded cluster) is the only causal condition that met this threshold for being considered a necessary condition, with a consistency value of 0.93 and a coverage value of 0.67. None of the other factors met this threshold for consistency.

Subsequency, three pathways (i.e. Solutions) leading to clusters with a high share of Green Innovation were identified. In order to identify the outcome (FS_INNO), we set the consistency cutoff at 0.85 and the PRI consistency cutoff at 0.65 (Greckhamer, 2016) and the frequency cut at 2, meaning more than two cases for each solution will be considered (see Table 5 for details on the truth table).

Table 5 - Truth Table Main Analysis.

FS_LQ	FS_BHN	FS_FOW	FS_OPP	FS_KNW	number	FS_INNO	raw consist.	PRI consist.	SYM consist.
0	1	1	1	1	5	1	0.94	0.83	0.90
1	0	0	0	0	9	1	0.86	0.68	0.70
1	0	0	1	1	22	1	0.87	0.68	0.69
1	1	1	1	1	20	0	0.83	0.62	0.73
1	1	0	1	0	11	0	0.85	0.59	0.63
1	1	1	1	0	6	0	0.87	0.59	0.60

Table 6 represents the three solutions, reporting the consistency and coverage values for each causal pathway, where unique coverage indicates the share of cases that the corresponding solution can explain. The overall solutions identified by fsQCA have a relatively high consistency value of 0.85, indicating a robust relationship between Green Innovation and the configurations, while the overall coverage is 0.56.

Table 6 – FsQCA solutions

Solution		**1**	**2**	**3**
Agglomeration				
LQ		⊗	●	●
Knowledge				
Patents per capita		●	●	⊗
Social progress				
Basic Human Needs		●	⊗	⊗
Foundation of Wellbeing		●	⊗	⊗
Opportunity		●	●	⊗
Consistency		0.94	0.87	0.86
Raw coverage		0.15	0.28	0.45
Unique coverage		0.08	0.04	0.20
Solution consistency	0.85			
Solution coverage	0.56			

Note: Full black circles (●) indicate the presence of a condition, and crossed open circles (⊗) indicate its absence (or negation). Large circles suggest core, or central conditions, whereas small circles indicate peripheral or contributing/complementary conditions.

Solution 1 includes the absence (i.e. negation) of Agglomeration as a core condition plus a high peripheral score on Knowledge and all the components of social progress. This pathway indicates the configuration for emerging clusters (clusters are present in the province portfolio but not yet at a specialized employment level, i.e. LQ greater than 1). The lack of a critical mass and the corresponding benefits from the externalities can still lead to adopting Green Innovation only in the case of a high level of external knowledge stock and a high level of all the dimensions of the social progress index, meaning a lack of institutional pressure. This solution suggests that the emerging cluster may suffer less from the constrain and boundaries of established institutional arrangements (i.e. myopia) (Maskell and Malmberg, 2007) and benefit from the high level of Knowledge and social progress in the territory.

The last two solutions (i.e. solutions 2 and 3) are pathways to Green Innovation for establishing clusters, where both high levels of Agglomeration and Institutional Pressure are present (given the low level of Basic Human Needs, as a core condition and Foundation of Wellbeing as a peripheral one). Within these two solutions, the differences lie in the high level of external Knowledge stock, which goes hand-in-hand with the high level of the Opportunity dimensions of social progress. Solution 2 has the presence of both, while Solution 3 has the absence of both. It is noteworthy that configuration 3 also has the highest unique coverage, covering 20% of all the cases (Ragin 2008).

A low score of Basic Human Needs and Foundations Of Wellbeing plays a pivotal role in causing Green Innovation, which has been expected given that these dimensions of social progress include phenomena such as environmental quality. As highlighted in the literature, a positive relationship exists between degrading environmental conditions and higher institutional pressure (Yuan et al., 2021). However, this pressure affects only firms part of a specialized cluster in the province's industrial portfolio. A possible explanation may be given by the fact that that established cluster (given the critical mass) contributes to shaping and

defining the Institutional adjustment, leading to an increased effect of isomorphic behaviours of firms (i.e. to seeking out legitimacy by adhering to a shred concept of how being a successful firm) (DiMaggio and Powell, 1983; Maskell and Malmberg, 2007; Tan et al.,2013).

Opportunity plays a critical role in possible paths in adopting green innovation. An explanation is that in territories with a high level of opportunity, clusters, both emerged and established, can benefit from a high level of Knowledge stock thanks to better access to human capital with advanced education and a more inclusive and well-working society in terms of the rule of law, personal rights, government effectiveness. As pointed out in the literature, a higher level of education influences firms' absorptive capacity, which contributes to green innovation (Aboelmaged and Hashem, 2019; Qi et al., 2021). Moreover, Firms involved in green innovation tend to collaborate with a more diverse set of actors in which also green social capital plays a significant role and leads to green innovation (Delgado-Verde et al., 2014; Chen and Wang, 2019; Christensen et al, 2019).

5. Conclusions

5.1. Research and policy implications

Our findings suggest implications both for theory and practice. In particular, our theoretical contribution to the debate on clusters and Green Innovation is three-fold.

First, we empirically contributed to this stream of literature by introducing a new type of analysis that goes beyond the focus on patents or surveys and is in contrast with the tendency to use data from small samples among green innovation researchers (Jahan Khan et al., 2021). Our analysis aims to observe the prevalence of green innovation in clusters systematically. It complements previous studies relying on case studies or firm-level surveys in the literature on clusters and Green Innovation using a large quantitative dataset and text-mining technics.

Secondly, we conceptually contributed to the extensive literature around factors and green innovation by introducing alternative configurations of factors causing Green Innovation in clusters, providing insights on the interplay among institutional pressure and the available external knowledge stock and agglomeration level.

Thirdly, our contribution is methodological as we present a new approach for measuring Green Innovation in clusters that can be replicated in other geographical contexts to enable cross-country comparisons. Replication of our methodology should begin with existing Cluster Mapping projects developed based on the methodology introduced by Delgado, Porter and Stern (2016). Since its introduction in the US over thirty years ago, many countries have developed cluster mapping projects alongside the European Cluster Observatory (e.g., Canada, Mexico, and India).

Our results also have practical implications for policymakers. Our research complements with a mapping tool (i.e. cluster mapping) for designing cluster-based policies aimed at the transition towards green industries or cluster initiatives for the emerging of new ones (Isaksen and Trippl, 2016; Holmen and Fosse, 2017; Steen and Hansen, 2018). Green policies are currently a high priority, as demonstrated by the recently European Commission's climate

change strategy - “The European Green Deal” (European Commission, 2019) - which aims to make the European Union climate neutral by 2050. Based on our research, policymakers and development agencies can identify specific cluster- and context-based opportunities to target industrial policies. They could assess the condition of the targeted context and industrial portfolio and find the closest causal pathways identified in this research to Green Innovation.

5.2. Limitations and future research

The present paper has some limitations that open avenues for future research.

First, we researched the firms of just one Italian region (NUTS-2), Lombardy. Despite being one of Italy’s most prosperous regions and diverse industrial specializations portfolio, future studies might also find more significant variation in the factors considered among developed and emerging economies, including a broader set of territories. Moreover, given the size, we need to cut off some industries for the sample of fewer than 50 firms.

Second, selecting green innovation topics is still subject to manual interpretation. We try to overcome this limitation by having the number of topics suggested by the procedure (instead of manually input in the model) and authors independent examinations. Future researchers may seek a more granular definition of the green innovation topics to identify the different types of green innovation (i.e. product or process), or a data-driven topics identification approach can be introduced, starting from large samples of firms practising green innovation, such as companies with particular environmental certifications.

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7. Appendix

Table A1 – Social Progress Index

Dimension	*Component*	*Variable*	*Source*
BASIC HUMAN NEEDS	Nutrition & Basic Medical Care	Avoidable mortality	BES (ISTAT)
		Infant mortality	BES (ISTAT)
		Fee-for-service specialty examinations	HFA (ISTAT)
		Overweight adults	HFA (ISTAT)
		Children with excess weight	HFA (ISTAT)
	Water & Sanitation	Leakage from municipal water supply	BES (ISTAT)
		Population exposed to flood risk	BES (ISTAT)
		Water supply per inhabitant	Acqua (ISTAT)
		Access to sewers	Ecosistema urbano (LEGAMBIENTE)
	Shelter	Irregularities in electrical service	BES (ISTAT)
		Housing space	BES (ISTAT)
		Housing rent sustainability	Scenari immobiliari
		Population exposed to the risk of landslides	BES (ISTAT)
	Personal safety	Voluntary homicides	BES (ISTAT)
		Other reported fatal crimes	BES (ISTAT)
		Widespread reported crimes	BES (ISTAT)
		Suburban road traffic fatalities	BES (ISTAT)
		Youth traffic fatalities	BES (ISTAT)
		Rate of fatal accidents and permanent disability	BES (ISTAT)
FOUNDATIONS OF WELLBEING	Access to knowledge	People with at least a high school diploma	BES (ISTAT)
		Inadequate literacy skills	BES (ISTAT)
		Numerical proficiency not adequate	BES (ISTAT)
		ICityRank	ICityRank (FPA)
	Access to Information & Communications	Reading index	QDV (il Sole 24 Ore)
		Broadband (Fttc)	Agcom
		Ultrabroadband (Ftth)	Agcom
		Libraries	QDV (il Sole 24 Ore)
	Health and wellness	Cancer mortality	BES (ISTAT)
		Life expectancy at birth	BES (ISTAT)
		Hospital emigration	BES (ISTAT)
		Sportsmanship index	QDV (il Sole 24 Ore)
	Enviromental Quality	Separate collection of municipal waste	BES (ISTAT)
		Electricity from renewable sources	BES (ISTAT)

		Availability of urban green space	BES (ISTAT)
		PM10	BES (ISTAT)
		PM2.5	BES (ISTAT)
		Municipal waste generated	BES (ISTAT)
		NO2	LEGAMBIENTE
		O3	LEGAMBIENTE
	Personal Rights	Electoral participation	BES (ISTAT)
		Rule of Law	IQI (Nifo e Vecchione, 2014)
		Active civic participation	IQI (Nifo e Vecchione, 2014)
		Prison crowding	BES (ISTAT)
		Corruption	IQI (Nifo e Vecchione, 2014)
		Institutional effectiveness	IQI (Nifo e Vecchione, 2014)
	Personal Freedom & Choice	NEET	BES (ISTAT)
		Gender pay gap	BES (ISTAT)
		Municipal services for children	BES (ISTAT)
		Density and relevance of museum heritage	BES (ISTAT)
		Density of historic green space	BES (ISTAT)
		Bicycle paths	QDV (il Sole 24 Ore)
		Cultural offerings	QDV (il Sole 24 Ore)
		Post-km offered by Tpl	BES (ISTAT)
	Inclusiveness	Female municipal administrators	BES (ISTAT)
		Municipal administrators under 40 years of age	BES (ISTAT)
		Accessible schools	BES (ISTAT)
		Nonprofit organizations	BES (ISTAT)
		Acquisitions of citizenship	QDV (il Sole 24 Ore)
	Access to Advanced Education	Gender gap labor participation	BES (ISTAT)
		College graduates and other tertiary degrees	BES (ISTAT)
		Transition to college	BES (ISTAT)
		Participation in continuing education	BES (ISTAT)

OPPORTUNITY

Table A2 – Green innovation topics

Industry	Coherence Score	Topics
Agricultural Inputs and Services	0.37	*No suitable Green Innovation topics found*
Apparel	0.38	riciclo softw cors internet comport rifer biodegrad conten scadenz tendenz pression realt polit riutilizz tel sublim recuper negoz guid sped conduttor pien regalal ecososten stropicc recuper informal bi-stretc ispir territor regul tradizion ispir pol primaver ambiental occasion estiv pezz slim
Automotive	0.34	compil impost armad util comfort sosten modul previst scop articol compart cultur atmosfer creativ esclusiv banal attent esigent insegn esalt fiduc signific team interlocutor cos attent pratic prend efficit atmosfer precision clientel differt fabbric armad consegn aziendal attent atmosfer marketing
Biopharmaceuticals	0.42	profarmac purezz eco-sostenibil millenn eco-sosten purytr sapient parafarmac satell compagin ipsen anonim comparizion abbon central profarmac purezz eco-sosten purytr millenn ril coltur tradizion pressurizz antiasmat profarmac eco-sostenibil cartace eco-sosten esport tradizion pianet influ fluid compagin profarmac purytr eco-sosten eco-sostenibil millenn
Biopharmaceuticals	0.42	nutrizional etic istanz sostenibil officin vegetal accompagn comprov leal episod
Business Services	0.42	end-to-end agil governanc leader scalabil viv intelligent adozion sostenibil cultur asset ecosistem sostenibil linux adozion complianc customer proatt leader partnership efficent 10deg pilastr iideg ecosistem sostenibil asset critic fattor anniversar qat emir saud nord arab asset finanz ambiental capac industrial provider sostenibil istruzion dipart progettual management precedent asset parol mapp
Communications Equipment and Services	0.40	class commerc iscrizion qualif centralin riciclo camer 1deg attest bigliett strad specc innesc macchin aeroport contest segretezz destin conseguent impatt
Construction Products and Services	0.30	rinnov assicur attenzion ester impost traspart gradin decor scegl esplor desider blocc rinnov partecip assum illustr chiav affin

		assicur caratterizz arred civil modern produttor ripristin pav rinnov vast macchinar cors esecut coordin scav aziendal direzion professional impatt qualific stud ottic onlin fiduc passion original compett tracc valor energ ester finalizz memorizz abilit energ marketing browser navig annunc certific visualizz vis energ illustr abilit performanc fier realt sap catalog strument efficit
Construction Products and Services	0.30	identific distill energ consegu modific descrizion adegu autorizz impost compil
Distribution and Electronic Commerce	0.51	strateg cultur promuov stor mir partecip apicoltor font condivid sostenibil voltur conguagl font sfid energ avvi requis fianc futur promuov consegut riport essenzial impatt atto pubblicitar stamp indoss sfid concett mirin notturn zer marz circol remot diagnost softw ben 35mm
Downstream Chemical Products	0.39	attenzion conosct sostenibil cosmes oggett idone eccellent document ambiental standard sostenibil mission repart annunc mad internazional sosten squadr econom cresc nazional certif ambiental team porr territor origin rigor quotid impiant clientel dosagg miscel smalt impiant deriv ambiental cottur ecolog gestion partnership pav garanz industr batter automatizz strateg manutenzion ambiental eccellt impiant tradizion impost fil cresc organizz dot legn navig ecolog
Downstream Chemical Products	0.32	scaric prezz assistt rinnov nazional certific prest ram pag consegn
Downstream Metal Products	0.35	emission manifest consum tutel vigent risc sosten regolament implement nobil
Education and Knowledge Creation	0.30	impatt regional magnif fiscal master messagg avvi patrimon istituzional energ sostenibil eccellent partnership autent comod produtt acceler leadership skill massimizz rendicont automatizz sostenibil chiud cartace scaric confer ragion facolt imprenditorial catalog sostenibil impatt aul nov dirigent leadership industrial specialist signif sent install manutenzion energ email luned rilasc provider famigl torn aggiunt increment addett fabbisogn automat fiduc interprofessional ester energ formator

		coaching distint account sostenibil messagg email dichiar management browser salv ragion affianc teor volontar accett network circol strad prefer riport amic industr modific download clinic vigent fabbisogn rendicont risolv efficient
Environmental Services	0.37	riciclagg vasett imball nolegg cern vagl vetr incolor autocarr stocc ragn metallurg hdpe classific lingu ferros riutilizz otton incener riciclagg puntual trarr riutilizz bottigl produttor imballagg suddivid esaur fusion lav nolegg tritur macin intermed ramif ferr stocc riutilizz riciclagg aqsiq polipropilen fusion riciclagg copert telef classific memorizz ditt statist persegu container compatt neutr ferros rigid mun riciclagg puntual imball login
Financial Services	0.29	fornitur material resident impatt acconsent corregg traffic lungimir restrizion ambient fusion zon energet agent dot soc accessor iter copertur convenzion
Food Processing and Manufacturing	0.36	specializz biolog industrial nutrizional certific compett produttor professional obiett support produtt logist filier mission ridurr compett produttor integr biolog sicur beness chimic biolog differt partner catalog filier ide prestig piattaform biolog nutrizional cereal element avanguard energ evit clientel formul svolg energet unit certific sport indirizz onlin nov piac global sottoporr golos artigianal visualizz racchiud onlin formazion rinnov filier info bont dolciar artigianal rinnov genuin specific passion magazzin biscott princip forz
Furniture	0.35	compil impost armad util comfort sosten modul previst scop articol attacc aziendal profession avval disporr prezz attent commercial requis manodoper fierist acquis stand risors allest annunc retail muse interag tracc
Hospitality and Tourism	0.49	spazios rinnov line event suit colazion aggiung perfett parchegg riguard
Information Technology and Analytical Instruments	0.32	energ cav industr catalog contraddistingu altern petrolchim avanguard tub impiant territor laborator forz scopr grupp sosten spedizion conosc filosof protett monitoragg industr origin clientel leader brev port iniz nasc rinnov

		verif accett mondial rif attenzion rinnov taratur specific vecc modif attenzion luog person nonc immed passion impatt parametr costru costitu apparecchiatur display business catalog analog nazional fier man avanguard pannell annunc intervent logist aliment produtt riconosc elev brev istitu efficient
Lighting and Electrical	0.34	facilit essenzial abbin rilev microprocessor acquist precedent luc customizz sostenibil sfrutt navig post elettron batter idone preved global piattaform energet impatt med analizz meccan raccolt tension riconosc protegg diffond strateg
Marketing, Design, and Publishing	0.40	*No suitable Green Innovation topics found*
Medical Devices	0.33	legisl consolid tutel rinnov preg sostenibil vigent territor competitiv protend energ stampagg montatur fotovolt mater invest scheletr istit attenzion specializz ide man osteointegr rinnov attent osse riabilit rotant omogene minimizz manutenzion anti barrier convenzional ambiental ovar telepinz grucc proteggifial iposcop
Metalworking Technology	0.40	limit polit preg ambiental procedur sol terr cont camb cre madrev eccellt fren fasteners appos ghier sostenibil internazional gener regol inquin accompagn intang aggrav propension responsabil ristruttur internazional impatt invest rocchett bienn energ modul ente internazional certific ordin ambiental inter pneumat mer ridurr element chimic barbecu qualit volt territor energ
Paper and Packaging	0.30	proced riciclabil automatizz invest cordonatur denomin famigl macchin pallettizz larg acqua riemp ricicl destin plastic fustell territor ondul posizion brev estend assum energet provinc ridurr ampiezz commess attual esclus cont
Plastics	0.32	ambiental avanz organ porr econom cred montagg sostenibil iniezion moltepl press consum legg cart energ qualific energet etic avanz automat
Printing Services	0.32	vast abbigl tess sicurezz compett avval eleg pol produtt energ tess calendar roll-up ecososten ades tradizional prezz serigraf allest competit log lasc ecolog attent quantit perc consum tagl ampli scegl packaging calendar impatt produtt ambiental capacit consult locandin espositor prepar

		etichett calendar bass mostr bigliett fierist impatt blocc espositor packaging
Production Technology and Heavy Machinery	0.37	impatt esport riscald accumul risc divent caten propr condivid ruol impatt energ volum stoccagg propr emission obiett ambiental ingress corrosion opzion scegl normat ten ambiental incorpor primar obiett carbon conform anion partnership colloid emission bollitor idraul qualific certif avvi liquid consum organ vigent tub design erog acqua combin normat automatizz saldator diesel operai ricamb ret saldatur sostenibil mapp hom mission chiud rif eccellt pul energet accett pannell elimin brevett uffic address info categor certif facil ambiental deriv ulterior corrett condizion
Recreational and Small Electric Goods	0.34	that clientel riusc fier conosct corn sostenibil pell impieg abilit immett parol bell manier accidental isol proven destin mater energet forz diffond percors ambiental guant energ intuizion alpin impatt ricicl costant trasfer propost visit indispens filosof pertinent sport ricicl iniz
Textile Manufacturing	0.39	obiett gest tessitur risors riduzion ricicl energ ambiental internazional sosten obiett pens sosten promuov invest progett consum tint risors finissagg sosten vast chiud impegn fantas elast decid poliest ambiental nylon tessitur set certif stamp ambiental laborator creazion internazional digital affianc
Transportation and Logistics	0.34	conosc pallet team aiut unic traspart disattiv impatt temperatur monitor buon mittent raccogl parzial chimic riduzion esprim risc container statist riduzion ottic tutel certif prest trasform ambient modus minim impieg raccolt fond otten global prossim process fiduc riduzion fil adegu propr impieg logic dir produttor ambiental deriv protocoll produzion scopr ambiental conosct serv monitor element realizz ente problemat riconosc compless
Upstream Metal Manufacturing	0.34	ridurr conosct aument cultur aspett camb elettr total analis difett otton imballagg email esit ridurr personalizz avven impres ester filettatur

		tub email estern precision efficient efficit ridurr avval parc pront tranciatur andar spessor energ scegl aziendal avanguard collabor util press
Video Production and Distribution	0.37	*No suitable Green Innovation topics found*
Vulcanized and Fired Materials	0.30	definizion lott cur matur tub princip prov attenzion laborator sostenibil assorb grupp energ sostenibil energet compett statist digital dimensional know-how interlocutor impres risc sostenibil grupp ambiental post person capacit impegn boccol mail commercializz impatt equilibr energet tir isol megl terr termic esclus piston cicl energet differenz carbon consolid static elastic buon esigent monitoragg medic diffond resistt conosct tess energ acid digital requis consolid avanguard brev personalizz indirizz energ pomp visualizz
Wood Products	0.32	chiar ediliz categor trasport invi flessibil tagl minim forest approfond infiss serr telai piant architett edil energet copert allumin accessor distingu disposit valut poic imballagg memorizz industrial macchinar energet serr link energ flessibil bosc trasfer aggiunt stor gen macchinar certif sinonim falegnamer energet rivend bisogn occup figl costruzion qualific leader cald laric leader rov solid cerc artig ambiental garanz vis