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The creation of cleantech startups at the local level: the role of knowledge availability and environmental awareness

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Abstract In this paper, we explore which local fac-tors affect the creation of cleantech startups in a geographical area. Specifically, we note that these startups combine innovation and attention to the environment. Thus, we consider two primary sets of local factors: the availability of scientific and technological knowledge and the environmental awareness of local governments and communities as the main drivers of the creation of cleantech startups. Using a dataset of 393 cleantech startups created between 2012 and 2014 and extracted from the Italian official database of innovative startups, we estimate negative binomial regressions whose dependent variable is the number of cleantech startups created in each of the 110 Italian provinces. The results highlight that both the local availability of scientific and technological knowledge and the local environmental awareness are crucial determi-nants of cleantech entrepreneurship in a geographi-cal area. We discuss the implications of these results for policymakers who intend to stimulate this type of entrepreneurship.

Keywords Cleantech startups · Local knowledge · Environmental awareness · Firm creation

1 Introduction

Cleantech firms are technology-oriented organizations that produce and/or commercialize Bany product, ser-vice, or process that delivers value using limited or zero nonrenewable resources and/ or creates significantly less waste than conventional offerings^ (Pernick and Wilder 2007, p. 2). Georgeson et al. (2014) note that the term Bcleantech^ has a fundamentally different meaning than the term Bgreentech^ popularized during the ‘70s and ‘80s. Indeed, while greentech refers to small, regulatory-driven markets characterized by the adoption of the Bend-of-pipe^ technological solutions of the past, cleantech addresses the foundations of environmental problems with new science, introducing innovations that can improve the productivity and efficiency of many diverse business processes. Thus, the cleantech industry encompasses a broad range of products, services, and technologies, including recycling; renewable energy (wind power, solar power, biomass, hydropower, and biofuels); information technology; green transportation; electric motors; green chemistry; composite materials; and lighting (Cumming et al. 2016). Currently, no one can deny the high potential of this industry in terms of financial returns and impact on the productive system. Additionally, due to the growing awareness of the dan-gers of climate change (Pernick and Wilder 2007), cleantech firms have become very attractive to private investors and drive job creation (Burtis et al. 2004).

The prominence of the cleantech industry, in turn, has urged policymakers to support it by issuing specific in-terventions to stimulate the creation and growth of cleantech firms.

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The need for governmental intervention is rooted in the peculiar nature of the cleantech business, which makes tailored incentives and regulations (e.g., anti-pollution norms) a fundamental pre-requisite for the development of the industry (for a recent discussion on the importance of regulations in this area, see Borghesi et al. 2015). First, environmental resources are "public goods" (Baumol and Oates 1988; van der Ploeg and Bovenberg 1994). Consequently, consumers are generally not inclined to pay for cleantech products and services as they only receive a limited portion of the benefits. Second, many governments are making efforts to reduce environ-mental degradation (e.g., OECD 2015), while supra-national organizations for environmental safeguards pro-mulgate international agreements and enforcement proto-cols (e.g., the Kyoto protocol, the Montreal Protocol on CFCs, and the EU Emissions Trading Scheme). As there is evidence that the international context affects the strategies of cleantech firms (e.g., Carraro and Siniscalco 1992), to promote the development of the industry countries must coordinate among each other on environmental policies and adhere to the aforementioned international agreements and protocols. Third, in the case of cleantech firms, the market failure caused by the public good nature of green business couples with the market failure associated with the high-tech nature of the industry. Due to appropriability concerns, in the absence of governmental intervention, cleantech firms' investments in the development and diffusion of new environmental-friendly technologies are likely less than the socially optimal ones (Jaffe et al. 2005).

The general interest in the cleantech industry has stimulated academic research on the topic. Scholars have explored how cleantech firms design their external collaborations and partnerships (Meyskens and Carsrud 2013; Hansen 2014), develop the markets for their prod-ucts (Doganova and Karnøe 2015), enter foreign mar-kets (Steinz et al. 2016), attract venture capital invest-ments (Giudici and Roosenboom 2004; Boyer 2011; Criscuolo and Menon 2015; Cumming et al. 2016), and raise capital through specialized crowdfunding por-tals (Bonzanini et al. 2016; Giudici et al. 2017).

Kapsalyamova et al. (2014) have shown that cleantech firms are not interested in relocating their activities to low-carbon cities, but their location choices primarily depend on factors of supply and demand. In this manner, the authors reveal a more general research issue: *which local factors favor/hamper the creation of cleantech firms* (*hereafter*: *cleantech startups*) *in a geo-graphical area*? To the best of our knowledge, no previous large-scale empirical study has answered this question, and we believe this is a relevant research gap. Preliminary evidence shows that the cleantech industry positively influences local development (e.g., Reardon and Weber 2014) to the extent that the creation of cleantech startups at the local level may enable the catching up and convergence of less developed areas. Understanding which characteristics of territories favor/hamper the creation of these firms is thus of great help in designing policies that stimulate the growth of the industry across regions and, ultimately, favor a harmonious economic development.

This paper makes a first step to fill this gap by taking stock from the large literature on the determinants of new firm creation across geographical areas (e.g., Armington and Acs 2002; Glaeser and Kerr 2009; Bonaccorsi et al. 2013). More precisely, following Burtis et al. (2004), we claim that cleantech startups share two main features. Namely, these firms aim at reducing humankind's impact on the environment, *and* they leverage new technologies to create environmentally friendly products and services. Accordingly, in developing our hypotheses, we focus our attention on two primary sets of local characteristics.[1] First, we argue that the availability of scientific and technological knowledge that spills over from local universities and incumbent firms has a positive impact on the creation of cleantech startups, as these startups can leverage this knowledge in developing their high-tech offering. Furthermore, we postulate that the creation of cleantech startups in a geographical area positively relates to the level of *environmental awareness* in that area, which we define as the sensitivity to environmental issues by local governments, firms, and residents. As we explain in the following section, such awareness informs the actions of local governments, which are then prone to issue policy measures to protect the environment, and is established in the local culture, creating a fertile context for cleantech entrepreneurship.

We test our hypotheses on a sample of 393 cleantech startups established between 2012 and 2014, selected from the list of Italian innovative startups (a particular class of startups introduced by Law Decree 221/2012; see Ghio et al. 2016, for further details). We use the

[1] We also consider that the creation of cleantech startups at the local level positively responds to favorable economic conditions. For instance, Eyraud et al. (2013) find that investments in the cleantech industry positively relate to economic growth, low interest rates in the financial markets, and high oil prices.

Italian province (NUTS3 level) as the unit of analysis and estimate negative binomial regressions whose dependent variable is the number of cleantech startups created in each province. We believe that Italy is a valuable context for our study. Indeed, the country has recently issued policy measures for sustaining entrepreneurship that responds to environmental and societal challenges (European Digital Forum 2016). Moreover, in Italy, local areas are highly heterogeneous in terms of the variables of interest.

The results of the econometric estimations are as we expected. The high-quality scientific knowledge produced by local technical universities and the stock of technological knowledge embodied in local patents positively influence the creation of cleantech startups in a geographical area. The efforts of local authorities in issuing environmentally friendly policies also have a positive effect. Finally, we find that the creation of cleantech startups at the local level positively relates to the environmental awareness of the local community.

In revealing the local factors that stimulate cleantech entrepreneurship, this paper advances our knowledge on the cleantech industry and, more generally, on green entrepreneurship. Indeed, it addresses and integrates two research issues that to date have received limited attention: the creation of cleantech startups and the influence of local contexts in this process. In so doing, this paper offers interesting insights for understanding the paths of transition to the green economy.

The remainder of the paper is organized as follows: Section 2 presents the research hypotheses. Section 3 outlines the methodology and the data used in the empirical analysis, while Section 4 shows the results of this analysis. Section 5 concludes the paper by highlighting its contributions to the scholarly and practical debate, acknowledging its limitations, and outlining directions for future research.

2 Research hypotheses

As mentioned in the introduction, we study the creation of cleantech startups in a geographical area by focusing on the effects of two sets of local factors: the *local availability of scientific and technological knowledge* and the *local environmental awareness*. In so doing, we fully acknowledge the nature of cleantech firms, which combines innovation with attention to the environment (Burtis et al. 2004).

First, in accordance with the knowledge spillover theory of entrepreneurship (Acs et al. 2009; Ghio et al. 2015), we postulate that the creation of cleantech startups in a geographical area positively depends on the availability of scientific and technological knowledge that spills over from universities and firms located in the area. This knowledge can be leveraged for creating new products and services and for solving technical problems (see Bonaccorsi et al. 2013 for a similar argument). In summary, it creates business opportunities that incumbent firms (which are large and bureaucratic) often discard and prospective entrepreneurs capture for creating their own ventures (Acs and Plummer 2005).

In particular, several researchers empirically demonstrate the prominence of university knowledge in stimulating local high-tech entrepreneurship (e.g., Audretsch and Lehmann 2005; Fritsch and Aamoucke 2013). One primary result is that the effects of university knowledge tend to be highly localized. Indeed, the transfer of university knowledge, which is largely tacit and not intended for commercial applications (Anselin et al. 1997; Ghio et al. 2016), requires face-to-face interactions among scientists and prospective entrepreneurs. Furthermore, Bonaccorsi et al. (2013) demonstrate that the spillover of university knowledge into local entrepreneurship depends on the scientific specialization of the universities. Their results suggest that technology-based entrepreneurship in a geographical area positively relates to the presence of universities that specialize in natural sciences (for startups operating in science-based manufacturing industries) and technical sciences such as engineering (for startups in knowledge-intensive services) in the same area. Conversely, university specialization in social sciences and humanities does not engender any significant effect. Based on the discussion above and considering that cleantech startups are a subset of the population of technology-based startups (Bjornali and Ellingsen 2014), we expect that the local availability of university knowledge in natural and technical sciences positively influences cleantech entrepreneurship in a geographical area. Hypotheses H1a and H1b are as follows:

H1a. The creation of cleantech startups in a geographical area positively relates to the local presence of universities producing knowledge in technical sciences.

H1b. The creation of cleantech startups in a geographical area positively relates to the local presence of universities producing knowledge in natural sciences.

Scholars frequently refer to patents by local inventors as a measure of the stock of local knowledge and acknowledge their impact on the creation of new ventures (Bae and Koo 2008). Colombelli (2016) shows that the stock of local knowledge (measured by the accumulated number of patent applications by local inventors) contributes to fostering the creation of innovative startups in Italian provinces. Similarly, we expect that the stock of technological knowledge embodied in patents has a positive effect on the creation of cleantech startups at the local level. Note that although local universities patent their inventions, we do not consider academic patents in this study. We intend to capture the effect of the local productive system, being the effect of the local university system assessed by H1a and H1b. Accordingly, H2 reads as follows:

H2. The creation of cleantech startups in a geographical area positively relates to local patents.

Furthermore, we adhere to the view that sociocultural aspects matter for green entrepreneurship (Cohen and Winn 2007; Dean and McMullen 2007). Accordingly, in addition to knowledge availability, we consider a second set of local factors that relate to *environmental awareness*, which we define as the sensitivity to environmental issues by local governments and communities (i.e., local firms and residents). This sensitivity translates into actions, attitudes, and behaviors that provide a favorable context for the creation of cleantech startups (see Meek et al. 2010, for a similar argument).

As we discuss in the introduction, governmental intervention is crucial for supporting the emergence of cleantech startups and channeling private investments into the industry. For instance, in a study of the clean energy segment, Bürer and Wüstenhagen (2009) observe that—all else being equal—investors are sensitive to the governmental interventions that favor clean energy firms. These interventions include feed-in tariffs, reduction of fossil fuel subsidies, introduction of programs such as the renewable fuel standard, incentives to encourage the adoption of new energy-efficient technology standards, carbon taxes, tax credits related to renewable energy production, and regulations for renewable portfolio standards. Investors perceive feed-in tariffs as the most effective policy, and this preference is even stronger among those based in Europe and with higher exposure to clean energy.

Expanding on this evidence, we expect that the environmental awareness of local governments, which results in the implementation of environmentally friendly policies and initiatives (e.g., tighter regulation of pollution, restrictions on energy efficiency in new buildings and industrial activity, and incentives for renewable energy generation), has a positive effect on local cleantech entrepreneurship. Indeed, support from local governments lowers the entry costs in the cleantech industry and generates new business opportunities for prospective entrepreneurs. Therefore, H3 is as follows:

H3. The creation of cleantech startups in a geographical area positively relates to the environmental awareness of the local governments.

Following the literature concerning green entrepreneurship, we posit that the environmental awareness of local firms and residents that originates from idiosyncratic experiences, lifestyles, ethical values, and traditions also plays a role in the creation of cleantech startups. Parrish (2010) documents that many entrepreneurs create cleantech startups because they value environmental protection and want to pursue societal wellbeing. Similarly, in a study of the emergent US wind energy sector between 1978 and 1992, Sine and Lee (2009) show that environmental organizations positively influence the creation of new market opportunities and thus encourage entrepreneurship in the industry. Specifically, in addition to having a direct impact, these movements enhance the effects of positive market conditions and skilled human capital. Moreover, we argue that the emerging nature of the industry stimulates the effect of environmental awareness of local communities on the creation of cleantech startups. As is the case with all firms operating in an emerging industry, cleantech startups must struggle to achieve legitimacy with potential investors, employees, and customers. Legitimacy is, in turn, fundamental to attracting resources (Zimmerman and Zeitz 2002). Cleantech startups can gain legitimacy by leveraging their focused identity on environmental issues (York and Lenox 2014). In geographical areas where local firms and residents have high environmental awareness, this process is likely easier. Accordingly, we formulate hypothesis H4.

H4. The creation of cleantech startups in a geographical area positively relates to the level of environmental awareness of local firms and residents.

As described in the following, we capture the environmental awareness of local firms based on their implementation of environmental management systems. The number of local non-profit associations that focus on environmental protection indicates the environmental awareness of local residents. Finally, we postulate that local environmental awareness is higher in areas where environmental disasters caused significant damage to the environment and, therefore, remain imprinted in the collective memory (e.g., Xu et al. 2013).

3 Data and methods

We test our hypotheses by considering the Italian province (NUTS3 level) as the geographical unit of analysis, and we run multiple regressions based on the following specification (Audretsch and Lehmann 2005 and Bonaccorsi et al. 2013 use a similar approach):

$$Startups = \exp\left(\alpha + \beta K + \gamma E + \delta CONTROLS + \varepsilon\right) \quad (1)$$

Based on Eq. (1), we relate the number of cleantech startups created in the focal province (*Startups*) to a set of explanatory variables that consider the local stock of technological and scientific knowledge (vector *K*), the local level of environmental awareness (vector *E*), and a set of control variables that capture the territorial characteristics (vector *CONTROLS*).

The dependent variable *Startups* is the number of cleantech startups created in each province between 2012 and 2014. Because *Startups* is a count variable, we use the negative binomial regression model to estimate Eq. (1). We prefer this model to the Poisson model, as our dependent variable suffers from over-dispersion (Greene 2003).[2] In the estimations, we also cluster data at the NUTS2 level (the 20 Italian regions) to account for possible spatial autocorrelation in our data (for a similar approach, see Baptista and Mendonça 2010).

The operationalization of *Startups* is not trivial, as official statistical registries do not contain a cleantech category. The literature defines cleantech startups as new technology-oriented firms (Bjornali and Ellingsen 2014) that develop and use innovative solutions with the goal of reducing humankind's impact on the environment (Burtis et al. 2004; Pernick and Wilder 2007; Cumming et al. 2016). To identify cleantech startups, we began collecting information concerning innovative startups operating in Italy using the official list (as of March 15, 2015) maintained by InfoCamere,[3] the public entity that manages the official register of Italian firms. The list comprises all Italian firms that Law Decree 221/2012 qualifies as *innovative startups*. The law defines a firm as an innovative startup if it is less than 5 years old, is small (less than €5 million in turnover) and innovative, i.e., it was created to develop, produce, and commercialize innovative products and services (for details see Ghio et al. 2016).[4] We then individually checked the list of innovative startups (3512 firms, of which 2777 were incorporated between 2012 and 2014). We obtained additional information concerning their mission, activities, and business model through publicly available sources (e.g., the firm's web site, balance sheet, and press releases) to identify those startups, which according to the definition provided above, have a clear cleantech orientation. Ultimately, we were able to identify 393 Italian cleantech startups created between 2012 and 2014,[5] which represent approximately 14% (i.e., 393/2777) of the Italian innovative startups' population.

Table 1 presents the geographical distribution of cleantech startups for the top 20 Italian provinces. The Province of Rome ranks at the top, with 31 cleantech startups (7.9% of the sample), followed by Bergamo and Milan (25 and 21, respectively). The Province of Naples (15 startups) leads the provinces located in the South of Italy.

For the explanatory variables in vector *K*, we measure the presence of knowledge spillovers from technical universities through a dummy variable (*Technical university*) that equals 1 if there is at least one university producing high-quality research in engineering and/or other technical sciences in the focal province. Then, we consider the presence of universities producing high-quality research in natural science in the focal province with the dummy variable *Natural science university*. To populate these two variables, we used data from the 2004 to 2010 Italian research quality assessment

[2] See the bottom of Table 5 in Section 5 for the chi-squared statistics of the likelihood ratio tests on over-dispersion parameters.

[3] http://www.infocamere.it.

[4] Moreover, the firm must meet (at least) one of the following additional requirements: R&D expenses to sales ratio must be greater than 15%, at least one third of the total workforce must possess a PhD or must have worked for at least 3 years in a research institute (or at least two thirds of the total workforce must possess an MSc degree) and the firm must be the holder or the licensee of (at least) one patent or intellectual right.

[5] Interestingly, 65 cleantech startups in our sample (16.5%) are university spin-offs (source: http://netval.it). In unreported estimates, we replicated the analysis when excluding these spin-offs from the sample. Results (available from the authors upon request) are substantially similar to those presented in Section 5.

Table 1 Number of newly-established cleantech startups in Italy (2012–2014) per province (top 20 provinces)

Ranking	Province	Number	Percent
1	Rome	31	7.9
2	Bergamo	25	6.4
3	Milan	21	5.3
4	Trento	19	4.8
5	Bologna	18	4.6
6	Turin	16	4.1
7	Naples	15	3.8
8	Modena	14	3.6
9	Pisa	10	2.5
10	Genua	10	2.5
11	Verona	9	2.3
12	Cagliari	9	2.3
13	Florence	8	2.0
14	Lecce	8	2.0
15	Venice	8	2.0
16	Brescia	7	1.8
17	Palermo	7	1.8
18	Ancona	7	1.8
19	Bari	6	1.5
20	Bolzano/Bozen	6	1.5
	Other 90 provinces	139	35.4
	Total	393	100.0

exercise (*Valutazione della Qualità della Ricerca*, VQR), performed by the National Agency for the Evaluation of Universities and Research Institutes (ANVUR). The VQR was intended to assess the quality of scientific research conducted by universities between 2004 and 2010. The assessment was based on peer review and, for articles indexed in the ISI and Scopus databases, on bibliometric analysis. For each scientific field, the ANVUR established a group of experts that evaluated more than 180,000 research products (including journal articles, monographs, essays, conference proceedings, patents, software, and databases) based on the relevance criteria of relevance, originality/innovation and (potential) impact on the international scientific community. This quality assessment produced a ranking of Italian universities in 14 scientific fields (1 mathematics and computer sciences; 2 physics; 3 chemistry; 4 earth sciences; 5 biology; 6 medicine; 7 agricultural and veterinary sciences; 8 civil engineering and architecture; 9 industrial and information engineering; 10 philological-literary sciences, antiquities and arts; 11 history, philosophy, psychology and pedagogy; 12 law; 13 economics and statistics; and 14 political and social sciences). For each scientific field, we considered the universities that the VQR ranked in the first quartile of Italian universities as producing high-quality research. Accordingly, *Technical university* equals 1 if there is at least one university ranked in the first quartile in scientific fields 8 or 9 in the focal province, while for *Natural science university*, we considered the scientific fields from 1 to 7. Finally, the stock of technological knowledge generated by incumbent firms is measured by the number of patent applications to the European Patent Office per 100,000 inhabitants in the province (*Patents*) as of 2011 (source: OECD).

Vector *E* refers to four variables that capture the level of environmental awareness of local governmental authorities and the community at large. For the former, we relied on the report *Ecosistema urbano 2012* by Legambiente[6] (League for the Environment), the most widespread environmental organization in Italy, with 20 regional branches and more than 115,000 members. The report contains a set of indicators concerning Italian provinces. To measure the level of environmental awareness of local governmental authorities, we extracted an index (*environmental policy index*) from this report that considers the extent to which the public authorities of a province adopted environmentally related initiatives (e.g., the presentation of an environmental balance, the adoption of policy initiatives with the goal of monitoring urban traffic and acoustic noise, or the implementation of the Sustainable Energy Action Plan (SEAP)).[7] We measure the level of environmental awareness of the local firms and residents through two "positive" and one "negative" measures. From the abovementioned report, we obtained the number of incumbent firms in the province with an ISO14001 certification as of 2011 (*ISO14001*). The ISO14001 certification is awarded to firms that implement and continuously improve their environmental management systems with a goal of minimizing the effect of their operations on the environment and comply with applicable laws, regulations, and other environmentally oriented requirements. The certification, which is mandatory to compete in international markets, is expensive,

[6] http://www.legambiente.it. See also Legambiente (2012).

[7] http://iet.jrc.ec.europa.eu/energyefficiency/covenant-mayors/sustainable-energy-action-plans.

and thus larger firms are likely to show a stronger propensity to apply for it.[8] Thus, to avoid confounding the effects of the firms' size, we computed *ISO14001* as the ratio between the number of incumbent firms with an ISO14001 certification and the number of incumbent firms with more than 50 employees in the province. Furthermore, we include the logarithm of the number of non-profit organizations with an environmentally related mission in the province (*environmental non-profit organizations*) as of 2011 (source: Italian National Statistical Office ISTAT). The wider the diffusion of associations engaging in environmental protection, the higher the environmental awareness of local residents and, ultimately, the larger the propensity of prospective entrepreneurs to consider environmental issues as priority objectives in their businesses. Finally, we built on the concept that negative events concerning environmental issues may stimulate "green" innovation (Miao and Popp 2014) and introduce a dummy variable (*environmental disaster*) that equals 1 for provinces that experienced environmental disasters due to human activity between 1976 and 2012 (see Table 6 in the Appendix for the list). Past negative experiences concerning failures in environmental protection, such as the toxic cloud caused by a chemical plant explosion in Seveso in 1976, should have relevant effects on the local environmental awareness. We expect that people living in these areas are particularly sensitive to avoiding such experiences and dedicate more support, resources, and investments to environment protection. In turn, this should stimulate the development of the cleantech industry.

Finally, the vector *CONTROLS* includes variables that address other local determinants of startup creation. Several researchers have shown that the local density of incumbent firms significantly affects new firm creation in a geographical area (e.g., Bonaccorsi et al. 2013; Acs and Plummer 2005). Therefore, we introduce the percentage of incumbent firms operating in high-tech industries (based on the Eurostat classification) in the province (*high-tech incumbents*).[9] Initially, we may expect that the creation of cleantech startups is lower when there are more incumbent firms in high-tech industries (since competition at the local level is larger). Alternatively, many firms in related high-tech industries may create additional positive spillover effects. Additionally, we consider the diversity of the local industrial system (Jacobs 1969) by including the Herfindahl-Hirschman Index, defined as the sum of the squared shares of incumbent firms in each industry (2-digit NACE classification) from the total number of incumbent firms located in the province (*HHI*). The higher the value of *HHI*, the lower the industrial diversity of the focal province. Following the previous discussion of the stronger propensity of larger firms to apply for the ISO14001 certification, we also include the percentage of incumbent firms with more than 50 employees (*large incumbents*). We consider heterogeneity in economic and wealth conditions across Italian provinces through the variable *Gdp per capita*. Local entrepreneurial activity likely relates positively to the gross domestic product of the province. We also control for demand characteristics of the focal province by introducing the variables *population density* (population per square kilometer in the province), *size* (size of the province in square kilometers), and *high-populated province* (i.e., a dummy variable that equals 1 if more than 500,000 people reside in the province). Finally, significant differences exist in the wealth, entrepreneurial activity, culture, and attitudes among regions in the North, Center, and South of Italy. Therefore, we include two area dummy variables that equal 1 if the province is located in the South (*South*) or in the Center (*Center*) of Italy.

Table 2 reports the detailed description of the variables in our study, Table 3 reports the summary statistics, and Table 4 reports the correlation matrix. We performed a variance inflation factor (VIF) analysis (see Table 7 in the Appendix), which suggests that multicollinearity is not a problem in our estimates. Indeed, the mean VIF is below the threshold of 5, while the maximum VIF is below the threshold of 10 (Belsley et al. 1980).

4 Empirical results

Table 5 shows the results of the negative binomial regression estimates. To ease the interpretation of coefficients, we standardized all continuous variables (mean zero, unit standard deviation). Model 1 includes the variables for scientific and technical knowledge spillovers (i.e., *Technical university*, *Natural science university*, and *Patents*) and the control variables. From model 2 to 5, we include, one by one, the variables for local

[8] We thank one of the two anonymous reviewers for having raised this important point.

[9] For details, please see http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Knowledge-intensive_services (KIS) and http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries.

Table 2 Variable description

Variable	Description
Dependent variable	
Startups	Number of cleantech startups in the province (years: 2012–2014; source InfoCamere)
Controls	
High-tech incumbents	Percentage of incumbent firms operating in high-tech industries (according to Eurostat classification) in the province (year: 2011; source: ISTAT)
HHI	Herfindahl-Hirschman Index of the shares of incumbent firms in each industry (2 digit NACE classification) in the province (year: 2011; source: ISTAT)
Large incumbents	Percentage of incumbent firms in the province with more than 50 employees (year: 2011; source: ISTAT)
Size	Size of the province in square kilometers (year: 2011; source: ISTAT)
Population density	Population per square kilometer in the province (year: 2011; source: ISTAT)
High-populated province	Dummy variable that equals 1for provinces with more than 500,000 inhabitants, zero otherwise (year: 2011; source: ISTAT)
Gdp per capita	Gross Domestic Product per capita of the province (year: 2011; source: ISTAT)
Center	Dummy variable that equals 1 for provinces of the Center of Italy
South	Dummy variable that equals 1 for provinces of the South of Italy
Main independent variables	
Technical university	Dummy variable that equals 1 if there is at least a university in the province producing high-quality research in engineering and other technical sciences (year: 2010; source: ANVUR)
Natural science university	Dummy variable that equals 1 if there is at least a university in the province producing high-quality research in natural sciences (year: 2010; source: ANVUR)
Patents	Number of patent applications to EPO per 100,000 inhabitants in the province
Environmental policy index	Legambiente index on environmental policy (year: 2011; source: Legambiente)
Iso14001	Ratio between the number of incumbent firms with an ISO14001 certification and the number of incumbent firms with more than 50 employees in the province (year: 2011; sources: Legambiente and ISTAT)
Environmental non-profit organizations	Logarithm of the number of non-profit organization with an environmental-related mission (year: 2011; source: ISTAT)
Environmental disaster	Dummy variable that equals 1 for provinces that experienced an environmental disaster (period 1976–2012) due to human activity (source: web sources)

environmental awareness (*Environmental policy index*, *Iso14001*, *Environmental non-profit organizations*, and *Environmental disaster*), while in model 6, we include all variables of interest. The likelihood ratio test under the null hypothesis that the over-dispersion parameter is zero (reported in the last row of Table 5) confirms that the negative binomial model is more appropriate than the Poisson model in all specifications.

Before analyzing the effects of the explanatory variables, let us focus on the control variables. We find that the local presence of incumbent firms is a relevant determinant for the creation of cleantech startups. The industry concentration index (*HHI*) is negative and significant (at the 5% level) in all estimates. This result suggests that the creation of cleantech startups is more likely in provinces with a more diversified industrial structure, while high local specialization is associated with low entrepreneurial activity in cleantech. The number of incumbent firms in high-tech sectors also correlates positively with the creation of cleantech startups (at the 5% level in the full model, i.e., model 6). This highlights that spillover and network effects have an effect, and the existence of other technology companies at the local level may reduce information costs and entry barriers. For the demand size effects, we find a positive and significant (at the 1% level in the majority of estimates) effect of being located in a highly populated province. Proximity to large urban agglomerates therefore significantly increases the chances of creating a cleantech startup. For the local economic and wealth conditions, the *GDP per capita* variable is not significant. Quite interestingly, provinces in the South of Italy

Table 3 Summary statistics on regression variables

Variable	Number	Mean	Std. Dev.	Min	Max
Startups	110	3.57	5.43	0	31
High-tech incumbents	110	2.95	0.77	1.06	5.95
HHI	110	0.07	0.01	0.05	0.10
Large incumbents	110	0.45	0.21	0.03	1.08
Size	110	2709.30	1577.10	211	7370
Population density	110	265.96	363.01	31.42	2651.35
High-populated province	110	0.35	0.48	0	1
Gdp per capita	110	31,439.13	8,535.74	14,855	60,890
Center	110	0.20	0.40	0	1
South	110	0.37	0.49	0	1
Technical university	110	0.21	0.41	0	1
Natural science university	110	0.29	0.46	0	1
Patents	110	38.49	38.62	0	222.40
Environmental policy index	110	47.24	24.72	0	100
Iso14001	110	7.69	5.11	2.94	47.20
Environmental non-profit organizations	110	3.69	0.69	2.08	5.82
Environmental disaster	110	0.09	0.29	0	1

The unit of analysis is the Italian province (NUTS3)

are more likely to begin new cleantech ventures. This result is robust across all the specifications, with the coefficient of *South* being positive and significant at 1% in all estimates. The largest availability of renewable resources (solar power and wind energy) in these provinces may explain this result. Another possible explanation is the higher presence of unemployed individuals in the provinces in Southern Italy. These individuals may be more likely to start new ventures, as their opportunity costs of self-employment are low (Carree et al. 2008; see also Horta et al. 2016 for a similar argument in the context of the creation of an academic spin-off).

Focusing on our research hypotheses, we find that technological spillover effects are consistent in the cleantech industry. The coefficient of *Patents* is positive and significant at the 5% level, suggesting that the local stock of technological knowledge embodied in patents positively relates to the number of cleantech startups in a geographical area (thus, hypothesis H2 is validated). More specifically, the average marginal effect[10] of *Patents* is 0.69 in model 6, meaning that a one standard deviation increase in *Patents* leads to an average increase of 0.69 cleantech startups in a geographical area. As the average number of cleantech startups in a province is 3.57, this is a non-negligible effect. For university knowledge spillovers, we find a positive and statistically significant coefficient of *Technical university* in most estimated models. That increase is strong in magnitude, as the average marginal effect of *Technical university* is 3.03 in model 1 (although both the magnitude and the significance decrease with the inclusion of all variables of interest).[11] Conversely, universities producing high-quality research in natural sciences do not have any significant effect. We, therefore, find support for hypothesis H1a, but not for hypothesis H1b.[12]

[10] The average marginal effect is the increase in *Startups* due to a one unit increase in the variable of interest. As all continuous regression variables have been standardized, one unit increase corresponds to an increase of one standard deviation. It is worth noting that the coefficients reported in Table 5 cannot be interpreted as marginal effects, given the non-linear nature of the negative binomial model.

[11] As mentioned in footnote 5, we repeated the analysis by excluding university spin-offs from the sample. We continue to detect a positive effect of *Technical university* on the local creation of cleantech startups. This result is in accordance with the theory that technical universities producing high-quality knowledge generate spillover effects that are captured by incorporating a cleantech startup.

[12] In an additional robustness check, we included among the covariates the number of universities in the focal province. The coefficient of this additional variable is not significant, while results remain substantially unchanged. Interestingly, *Technical university* is still positive and significant at 10%.

Table 4 Correlation matrix

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	*Startups*	1.00																
2	*High-tech incumbents*	0.59	1.00															
3	*HHI*	− 0.23	− 0.42	1.00														
4	*Large incumbents*	0.46	0.47	− 0.41	1.00													
5	*Size*	0.30	0.07	− 0.14	0.00	1.00												
6	*Population density*	0.39	0.43	− 0.02	0.27	− 0.30	1.00											
7	*High-populated province*	0.54	0.34	− 0.17	0.34	0.42	0.34	1.00										
8	*Gdp per capita*	0.44	0.49	− 0.21	0.76	0.00	0.25	0.19	1.00									
9	*South*	− 0.19	− 0.28	0.16	− 0.60	0.14	− 0.11	− 0.05	− 0.79	1.00								
10	*Center*	0.00	0.00	− 0.04	− 0.15	− 0.02	− 0.07	− 0.17	0.10	− 0.39	1.00							
11	*Technical university*	0.57	0.33	− 0.18	0.16	0.33	0.20	0.28	0.23	− 0.12	0.08	1.00						
12	*Natural science university*	0.42	0.37	− 0.25	0.26	0.27	0.20	0.29	0.30	− 0.16	0.03	0.46	1.00					
13	*Patents*	0.36	0.38	− 0.33	0.76	− 0.05	0.12	0.19	0.72	− 0.63	− 0.03	0.21	0.28	1.00				
14	*Environmental policy index*	0.47	0.27	− 0.18	0.48	0.12	0.16	0.28	0.50	− 0.44	− 0.03	0.29	0.21	0.42	1.00			
15	*Iso14001*	− 0.23	− 0.35	0.32	− 0.48	− 0.09	− 0.19	− 0.32	− 0.19	0.16	0.06	− 0.08	− 0.19	− 0.25	− 0.11	1.00		
16	*Environmental non-profit organizations*	0.65	0.44	− 0.24	0.58	0.50	0.24	0.64	0.54	− 0.36	0.00	0.46	0.37	0.44	0.37	− 0.40	1.00	
17	*Environmental disaster*	0.19	0.17	− 0.03	0.05	− 0.05	0.36	0.24	0.02	0.08	− 0.16	0.07	− 0.06	− 0.05	0.02	− 0.07	0.09	1.00

Table 5 Econometric results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
High-tech incumbents	0.173*	0.182*	0.186**	0.165*	0.178**	0.187**
	(0.089)	(0.094)	(0.090)	(0.092)	(0.084)	(0.085)
HHI	− 0.233**	− 0.221**	− 0.227**	− 0.262**	− 0.226**	− 0.229**
	(0.102)	(0.102)	(0.101)	(0.108)	(0.100)	(0.098)
Large incumbents	0.281*	0.273*	0.344*	0.201	0.306	0.317
	(0.166)	(0.155)	(0.201)	(0.177)	(0.190)	(0.224)
Size	0.121	0.084	0.116	− 0.007	0.112	− 0.123
	(0.085)	(0.074)	(0.082)	(0.095)	(0.089)	(0.102)
Population density	0.098	0.071	0.095	0.053	0.048	− 0.063
	(0.103)	(0.083)	(0.102)	(0.093)	(0.102)	(0.078)
High-populated province	0.853***	0.779***	0.894***	0.616***	0.811***	0.449*
	(0.132)	(0.160)	(0.135)	(0.167)	(0.135)	(0.187)
Gdp per capita	0.154	0.108	0.123	0.061	0.110	− 0.106
	(0.213)	(0.204)	(0.235)	(0.230)	(0.197)	(0.207)
South	0.857***	0.998***	0.868***	0.824***	0.823***	0.997***
	(0.292)	(0.326)	(0.295)	(0.296)	(0.247)	(0.287)
Center	0.484**	0.510*	0.510**	0.362	0.547**	0.505*
	(0.235)	(0.263)	(0.239)	(0.225)	(0.249)	(0.259)
Technical university	0.755***	0.652***	0.732***	0.617**	0.735***	0.440*
	(0.261)	(0.245)	(0.263)	(0.258)	(0.274)	(0.235)
Natural science university	0.098	0.129	0.119	0.152	0.158	0.293
	(0.185)	(0.187)	(0.201)	(0.184)	(0.182)	(0.204)
Patents	0.210**	0.198**	0.203**	0.198**	0.224**	0.190**
	(0.086)	(0.083)	(0.083)	(0.081)	(0.090)	(0.083)
Environmental policy index		0.216**				0.242***
		(0.109)				(0.085)
Iso14001			0.112			0.153
			(0.146)			(0.144)
Environmental non-profit organizations				0.359**		0.464***
				(0.178)		(0.134)
Environmental disaster					0.452**	0.657**
					(0.229)	(0.257)
Constant	− 0.231	− 0.253	− 0.253	− 0.117	− 0.281	− 0.238
	(0.214)	(0.225)	(0.205)	(0.198)	(0.230)	(0.212)
N	110	110	110	110	110	110
Log-likelihood	− 202.72	− 200.19	− 202.47	− 200.54	− 201.26	− 193.146
LR test on over-dispersion $\chi^2(1)$	33.2***	18.7***	32.9***	27.1***	25.2****	4.2**

Negative binomial regression estimates with clustered standard errors at the NUTS2 level. The dependent variable is the number of cleantech startups in the province

*, ** and *** indicate significance at the 10%, 5% and 1% level, respectively

For variables related to local environmental awareness, we find support for hypothesis H3 concerning the positive effect that local governments' promotion of environmentally friendly policies has on cleantech entrepreneurship. In models 2 and 6, the coefficient of *Environmental policy index* is positive and significant (in model 6 at the 1% level with a marginal effect of 0.88). We also find support for hypothesis H4. The environmental awareness of the local community has an impact on startup creation in the cleantech industry. In model 6, *environmental non-profit organizations* and *environmental disaster* are both positive and statistically significant at conventional significance levels. More specifically, we find strong evidence associated with the presence of non-profit organizations whose mission is environment protection. The coefficient of *environmental non-profit organizations* is significant at the 1% level, while its marginal effect is 1.69. For *environmental disaster,* we continue to detect a positive effect, significant at 5%, with a marginal effect of 2.40. Conversely, ISO14001 is not significant in either model 4 or 6.

Finally, one can argue that the positive effect of the *Environmental policy index* on the creation of cleantech startups may depend on unobserved heterogeneity that our econometric models do not consider. For instance, prospective entrepreneurs willing to incorporate cleantech startups might exert pressure on local governments to implement environmentally friendly policies. The more these prospective entrepreneurs are and the stronger is their influence on the local community, the higher is the likelihood that (i) a cleantech startup is incorporated and (ii) environmental-friendly policies are actually implemented by local governments to avoid negative reputational effects. To address this endogeneity concern, we resort to an instrumental variable approach. We run a negative binomial regression model with the same specification presented in model 2, but having the share of children (0–3 years old) in the province that used childcare services offered by local institutions (*childcare*) as an instrument for *Environmental policy index*. To be effective, an instrument must be highly correlated with the independent variable it intends to predict without being correlated with unobserved factors (included in the error term) that might affect the dependent variable. The rationale for our choice is that local institutions that invest in the care of the youngest generations should have a natural inclination to implement policies addressing social issues in general and environmental issues in particular. In summary, we expect that these local institutions are more willing to work to create "a better world" for their current and future residents. As expected, *childcare* is a strong predictor of *Environmental policy index* (*p* value = 0.001) when regressed with other independent variables. However, it is unlikely that local governments would be more willing to implement childcare services due to direct pressure exerted by influential, prospective cleantech entrepreneurs. The results from instrumental variable regression (reported in the Appendix) confirm the positive effect of *Environmental policy index* on the local creation of cleantech startups.

5 Conclusions

Policymakers and society as a whole are increasingly interested in reducing humankind's impact on the environment and in promoting sustainable growth (OECD 2015). Thus, understanding what drives the creation of high-tech, environment-friendly startups is of fundamental importance. These firms contribute to technological progress in a sustainable manner and lead the transition toward a green economy, which safeguards the environment and, more generally, creates a fairer society (EEA 2014). Based on these premises, this paper studies what determines the creation of *cleantech startups* at the local level. In so doing, it adds to scholarly conversations in three primary areas.

First, the paper documents the relevance of the cleantech industry in innovative entrepreneurship. Our data show that the creation of cleantech startups is a non-negligible phenomenon; it represents approximately 14% of the Italian innovative startups' population. Second, prior studies on the creation of cleantech firms (see Bjornali and Ellingsen 2014 for a review) have disregarded the effects of local factors on cleantech entrepreneurship. We address this gap by bridging the literature on how local characteristics affect startup creation (e.g., Armington and Acs 2002; Glaeser and Kerr 2009; Bonaccorsi et al. 2013; Colombelli 2016) with emergent research of the cleantech industry. Thus, the paper also complements the debate on the importance of local factors—and particularly local policies—in shaping environmentally friendly behaviors of firms in a geographical area. A recent contribution within this debate is the work of Cainelli et al. (2015), which explored how firms located in regions characterized by stricter waste policies and the presence of more firms featuring improved waste collection are more likely to adopt environmental innovations.

Third, by documenting the prominent role of the local availability of scientific and technological knowledge in the creation of cleantech startups at the local level, we extend insights from the knowledge spillover theory of entrepreneurship (see Ghio et al. 2015 for a review of this literature) to the cleantech industry. Finally, originally enough, the paper highlights the importance of the local *environmental awareness*, which we relate not only to the actions of local governments, but also to the sensitivity to environmental issues of local communities.

The paper has limitations that provide opportunities for future research. First, it focuses on an Italian context, which we deem to be particularly appropriate for studying cleantech entrepreneurship. However, the focus on a single country limits the results' generalizability and does not allow evaluation of the role of national environmental policies in cleantech entrepreneurship. Accordingly, we welcome future contributions that replicate our research in other countries, perform cross-country comparisons, and relate the creation of cleantech startups to national policies. In particular, we encourage scholars to compare and contrast the creation of cleantech startups in the diverse European countries.

Second, we use a quantitative approach based on cross-sectional data, which limits our ability to understand all the nuances of the phenomenon under investigation. We encourage researchers to overcome this limitation by leveraging other methodological approaches. In-depth case studies of how the process of creation of cleantech startups unfolds in specific geographical areas should significantly advance our knowledge concerning the direct and indirect participants of this process (prospective entrepreneurs, universities, local institutions, and local communities) and their relative impact on the creation of cleantech startups. Moreover, as cross-sectional data do not consider the temporal dimension of startup creation at the local level, we suggest further studies based on panel data.

Third, we lack detailed information concerning the environmental policies issued at the regional and provincial level because Italy has no central repository that collects these policies, which are under the responsibility of many authorities. This is a shortcoming of our research and we invite scholars studying cleantech entrepreneurship to gather information concerning environmental policies at a sub-national level. Finally, we use the province as the level of analysis. Further studies may explore the phenomenon at the firm and individual level. At the firm level, it would be interesting to obtain information concerning cooperation among cleantech startups and local universities, for example, by assessing the existence of research contracts. Likewise, at the individual level, we should learn more concerning the motivations and factors that inspire individuals to create a cleantech startup. Do these entrepreneurs create cleantech startups because they care about environmental problems? Do they use the scientific and technological knowledge that spills over from universities and incumbent firms as a basis for creating their ventures? Again, case studies that allow for the collection of more detailed information may be of great assistance in answering these questions.

Despite these limitations, our study has interesting implications for policymakers. First, according to our results, local governments can directly sustain cleantech entrepreneurship by engaging in policy initiatives tailored to cleantech entrepreneurs. In Italy, regional governments (NUTS2 level) have an important role since they have direct responsibility for issues related to health and environment protection, urban planning, and policies concerning firm competitiveness. Moreover, regions receive funding from the European Union to finance grants for public and private entities with goals of protecting the environment, stimulating technology and entrepreneurship, and favoring the transition to a green economy. Town councils have no legislative power in Italy, but, among other responsibilities, they define the criteria for the construction of buildings (that may be more or less "green") and implement action plans such as green procurement, energy efficiency, and smart mobility. In addition, policymakers can stimulate cleantech entrepreneurship through indirect levers. Specifically, they can promote the diffusion of scientific and technological knowledge by universities and incumbent firms across territories. Likewise, they can support the creation of this knowledge by appropriately incentivizing universities and innovative firms. Additionally, they can increase the environmental awareness of people that reside in an area through actions that promote ecologically sustainable lifestyles and sustainable work practices. In our view, these actions are of critical importance as they can magnify the effect of environmental policies. For instance, Sine and Lee (2009) show that the efficacy of public policies in stimulating entrepreneurial growth by firms in the renewable energy industry depends on prevailing social norms (e.g., consumption norms and norms of cooperation).

Appendix

Table 6 List of environmental disasters due to human activity in the period 1976–2012 in Italy

Year	Province	Description
1976	Monza and Brianza	Dioxin cloud
1979	La Spezia	Toxic waste
1984	Siracusa	Dispersion of depleted uranium
1985	Trento	Tailings dam collapse
1988	Massa and Carrara	Toxic cloud
1991	Genua	Dispersion of crude oil
1994	Naples	Toxic waste
2007	Pescara	Toxic waste
2008	Catania	Toxic waste
2010	Monza and Brianza	Dispersion of crude oil
2011	Cagliari	Dispersion of depleted uranium
2012	Vicenza	Toxic waste

Table 7 Variance inflation factor

Variable	VIF
Gdp per capita	5.60
Large incumbents	4.95
South	4.55
Environmental non-profit organizations	3.92
Patents	3.11
Size	2.88
High-populated province	2.45
Population density	2.28
High-tech incumbents	2.00
Center	1.85
HHI	1.68
Technical university	1.67
Iso14001	1.62
Environmental policy index	1.62
Natural science university	1.53
Environmental disaster	1.28
Mean VIF	2.69

Table 8 Instrumental variable regression

	OLS Dep. Var: *Environmental policy index*	IV negative binomial Dep. Var: *Startups*
High-tech incumbents	− 0.116	0.184
	(0.110)	(0.129)
HHI	− 0.096	− 0.292
	(0.099)	(0.142)
Large incumbents	0.068	0.193
	(0.164)	(0.195)
Size	0.117	0.171
	(0.116)	(0.133)
Population density	0.099	0.131
	(0.114)	(0.082)
High-populated province	0.367	0.677***
	(0.230)	(0.246)
Gdp per capita	− 0.108	0.140
	(0.192)	(0.273)
South	− 0.556*	1.269***
	(0.334)	(0.463)
Center	− 0.530**	0.670*
	(0.259)	(0.356)
Technical university	0.328	0.475*
	(0.234)	(0.259)
Natural science university	− 0.029	0.106
	(0.206)	(0.231)
Patents	− 0.093	0.256**
	(0.138)	(0.112)
Environmental policy index		0.582**
		(0.296)
Childcare	0.070***	
	(0.019)	
Constant	− 0.808**	− 0.361
	(0.343)	(0.272)
N	110	110

Column 1: OLS regression. The dependent variable is the environmental policy index of the province. Column 2: instrumental variable negative binomial regression with clustered standard errors at the NUTS2 level. The dependent variable is the number of cleantech startups in the province. The instrument is the share of children (0–3 years old) in the province that used childcare services offered by local institutions

*, ** and *** indicate significance at the 10%, 5% and 1% level, respectively

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