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RESEARCH ARTICLE

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New ventures in Cleantech: Opportunities, capabilities and innovation outcomes

Febi Jensen[1] | Hans Lööf[2] | Andreas Stephan[3]

[1] School of Business, Economics and Law, University of Gothenburg, Gothenburg, Sweden
[2] Centre of Excellence in Science and Innovation Studies, Royal Institute of Technology, Stockholm, Sweden
[3] Jönköping International Business School, Jönköping University, Jönköping, Sweden

Correspondence
Andreas Stephan, Jönköping University, Jönköping International Business School, 551 11 Jönköping, Sweden.
Email: andreas.stephan@ju.se

Abstract

Facing the challenge of climate change, innovations that imply environmental benefits create business opportunities for entrepreneurs. This paper analyzes innovation capabilities of startups in Cleantech and how the innovation outcomes of those startups develop over time. Based on the Mannheim Foundation Panel and applying propensity score matching, a cohort of 567 Cleantech startups is analyzed and compared with a control cohort of non-Cleantech startups. We find that startups in Cleantech have, on average, higher technological capabilities compared with all other startups. Our econometric evidence shows that Cleantech startups are more likely to combine existing technology in a novel way. Finally, we find that Cleantech startups develop more market novelties in subsequent years when compared with their control group peers.

KEYWORDS

capabilities, Cleantech, governmental support, green innovations, innovative startups

JEL CLASSIFICATION

M13; O13; O25; O31

1 | INTRODUCTION

To address the challenge of climate change and scarce natural resources, many countries have developed policies that aim at fostering the Cleantech sector. Consumer demand for environmentally friendly technologies has been high thereby also creating opportunities for entrepreneurs to develop novel technologies that are cleaner and conserve more energy and resources. Globally, the lead markets for green products, processes, and services are estimated to have a volume of several billion euros (BMUB, 2014). This creates opportunities for the establishment and growth of Cleantech startups with innovative products, processes, or services. However, not much is known regarding the innovation contents of those startups. Do they develop new products based on own R&D, or do they mainly apply existing technology? Do they succeed in creating market novelties, or do they mainly provide existing products or services?

A unique and yet unexplored opportunity for a systematic analysis of these companies is provided by the Mannheim Foundation Panel, which allows us to identify Cleantech startups and a comparison group of non-Cleantech startups with similar characteristics as a control group. Previous studies have highlighted that the development of clean technology startups is driven by external factors, such as technological and market opportunities (Giudici, Guerini, & Rossi-Lamastra, 2017; Malen & Marcus, 2017). Surveying the literature on startups in Cleantech, Bjornali and Ellingsen (2014) find surprisingly few studies providing systematic evidence on the innovative capabilities of Cleantech firms, and how these firms exploit and realize market opportunities. In addition, factors that influence innovation activities of Cleantech startups are as of yet left unexplored. The objective of our paper is to fill this gap.

A key feature of our paper is that we analyze the technological and innovation capabilities of Cleantech startups and then link these capabilities to the likelihood of generating Cleantech solutions and the general innovation outcomes of those startups. Cleantech startups, in general, are a heterogeneous group of firms operating from a business model that offers products or services that reduce negative environmental externalities. The environmental benefits of Cleantech products or services include higher levels of recyclability and energy efficiency, a reduction in the use of and impact on natural resources, and lowered noise emissions. The realization of entrepreneurial opportunities in Cleantech depends on the development of specific strategies for this business model (Amankwah-Amoah, Danso, & Adomako, 2019; Tang, Walsh, Lerner, Fitza, & Li, 2018; Teece, 2010). Consequently, it is essential to understand whether and how startups will gain a competitive advantage (i.e., from innovation activities) when the exploitation of entrepreneurial opportunities is combined with the use of innovation capabilities and other internal and external resources (Jantunen, Puumalainen, Saarenketo, & Kyläheiko, 2005). In order to explore these factors more deeply, our paper focuses on entrepreneurial opportunities, technological and innovation capabilities, and innovation outcomes—defined as market novelties—for Cleantech startups.

Our measures of startups' technological and innovation capabilities include several types of assets available to startups when developing their business. First and foremost, we assume that the background of the founder(s) matters. We expect that knowledge, both in terms of educational background, and experience are important. Therefore, we investigate the founder's educational degree or specific skills, to determine whether a founder's science, engineering, or business degree are important characteristics. Romijn and Albaladejo (2002) discuss the importance of a founder's background, specifically, when technological startups have founders with engineering or science backgrounds. Technological startups involve intricate innovation and technology that is determined by a founder's human capital (Almus & Nerlinger, 1999). We address the question of whether the innovation outcomes of Cleantech startups are contingent on performing continuous R&D. We provide evidence regarding the importance of patents in Cleantech startups' innovation activities and outcomes. As previous studies have highlighted the importance of government support and access to funding for green startups (Tsoutsos & Stamboulis, 2005), this study also explores the role of government support and access to finance on the success of creating new ventures in Cleantech.

Our paper makes a number of contributions to the literature. First, to our knowledge, this is the first study that incorporates Cleantech startups' opportunities, capabilities, and innovation using comprehensive and detailed firm-level panel data allowing for a comparison between Cleantech new ventures and other new firms. Second, after defining a control group with the help of propensity score matching (PSM), we find that Cleantech startups have a higher likelihood of focusing on innovation and technological leadership as their primary business strategy. Third, based on the multinomial logit estimation, we can show that Cleantech startups produce more novel technologies than non-Cleantech startups. The higher innovation content of Cleantech startups is driven by technological capabilities and specific characteristics of the founder. For all startups, both the founder's industry experience and educational background are positively correlated with creating novel technology. Founders with engineering degrees are an important asset for Cleantech startups, and most Cleantech founders have an engineering background. The overall conclusion of our empirical analysis is that Cleantech startups do perform better, on average, than non-Cleantech startups conditional on their innovation capabilities, for example, their continuous R&D activity and holding patents. Finally, our research may inspire policy makers and entrepreneurs to promote the evolution of environmental technology as a key transformation to a green economy. By knowing the capabilities and innovation outcomes of Cleantech startups, it may become easier to develop policies that encourage new business ventures to focus on these assets and capabilities that enhance innovation performance.

The remainder of the paper is organized as follows. Section 2 gives some background details about Cleantech, provides a review of relevant literature and develops our hypotheses. Section 3 describes the data and empirical approach. Section 4 reports both the descriptive and econometric results. Section 5 offers some concluding remarks.

2 | LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

In recent years, there has been a growing policy interest in addressing the issue of climate change. The development of clean technology by startups is generally considered to be an important aspect in the transition to sustainable economic growth (Eyraud, Clements, & Wane, 2013; Sæther & Amundsen, 1996). Clean technology is a rather broad concept, but most studies define it as new products or services that generate higher energy efficiency, for example, climate-smarter buildings or less polluting transportation, or the introduction of environmentally improved production processes (Dechezleprêtre, Martin, & Mohnen, 2014). A firm can be considered as “Cleantech” if it helps to protect the environment by delivering products, services, or processes that reduce the consumption of nonrenewable resources and/or creates significantly less waste than conventional offerings (Pernick & Wilder, 2007). Accordingly, Cleantech startups are broadly assumed to be important drivers of environmentally friendly solutions and climate change mitigation.

Given the significant policy interest in Cleantech startups, one might expect an extant literature on this category of firms; however, this is not the case. Bjornali and Ellingsen (2014) provide a review of papers about Cleantech published in leading journals of management, business, and entrepreneurship and find that only very few papers deal specifically with the conditions and performance of Cleantech startups. Questions regarding the driving forces for starting Cleantech companies and whether Cleantech startups are likely to be more innovative than other newly started companies have not been addressed in the previous literature.[1] The existing literature distinguishes between three categories of factors that promote startups in new technology: individual, firm-specific, and external. The first group refers to the characteristics of the founder or the team of founders. Ample empirical literature shows that these factors are important for the viability of new firms (Acs & Audretsch, 2003; Almus & Nerlinger, 1999; Bertoni, Colombo, & Grilli, 2011; Gilbert, McDougall, & Audretsch, 2006). Furthermore, the knowledge and skills of the founder based on educational background and experience have been identified as important drivers. A study by Romijn and Albaladejo (2002), for instance, emphasizes the importance of an engineering or science background for founders of technological startups. Among others, Almus and Nerlinger (1999) as well as Bloom and Van Reenen (2011), provide comprehensive evidence on the relationship between the founder's human capital and the company's technology and innovation capabilities. Doran and Ryan (2016) confirm that firms exploiting market and technological opportunities for the supply of environmentally responsible features are associated with high innovation capabilities. This leads to the following first hypothesis that is tested in our subsequent empirical analysis:

Hypothesis 1. *Cleantech startups have on average higher technological and innovation capabilities compared with non-Cleantech ventures.*

The realization of entrepreneurial opportunities in these new firms is considered to be associated with firms' business model and strategy (Amankwah-Amoah et al., 2019; Jantunen et al., 2005; Tang et al., 2018; Teece, 2010). A key issue for Cleantech startups is how the entrepreneurial opportunities are combined with the use of firms' internal capabilities. An extensive literature has shown that patents as well as the amount of time and resources invested in R&D are two of the most important proxies for technological capabilities (Baum, Lööf, & Nabavi, 2019; Cefis & Orsenigo, 2001; Peters, 2009). Some studies indicate that such supply-driven innovations (technological-push) are particularly important in Cleantech (Horbach, 2008; Rehfeld, Rennings, & Ziegler, 2007). Technological trajectories consist of appropriability decisions, opportunity recognition, and knowledge cumulativeness. According to Dangelico (2017), new technologies and environmental commitment related to technological aspects are relevant factors that drive the radical nature of green products or services. This leads to our second hypothesis regarding the technological character of solutions developed by Cleantech startups:

Hypothesis 2. *Given their higher technological capability, Cleantech startups are more likely to develop own technology of cutting-edge character compared with non-Cleantech ventures.*

Technological capabilities are nurtured by firms' internal innovation capabilities (Triebswetter & Wackerbauer, 2008). Improvements in a firm's technological and innovation capability, for example, the intensity and continuity of R&D activities, lead to a higher likelihood of introducing new products and services on the market (Klette & Kortum, 2004). Sáez-Martínez, Díaz-García, and Gonzalez-Moreno (2016) study eco-innovation in startups and find that both the combination of technological trajectories and R&D strategies are important drivers of eco-innovation in young firms. Some authors have suggested that entrepreneurs motivated by ethical concerns may be more successfully in green innovations (York & Venkataraman, 2010). A study by Shu, Zhou, Xiao, and Gao (2016) corroborates the notion that a commitment by firms to transition to green management or natural environment leads to radical innovation rather than incremental innovation. These findings are summarized in our third hypothesis as follows:

Hypothesis 3. *Given their higher technological capability, Cleantech startups are more likely to introduce significant market novelties compared to non-Cleantech ventures.*

A number of studies have found that stricter environmental regulation in the form of carbon taxes, cap and trade, or environmental standards stimulates innovation ("weak" version of Porter hypothesis, see Porter & Van der Linde, 1995).[2] It has also been argued that Cleantech is still a sector with limited profitability (Bjornali & Ellingsen, 2014) and that Cleantech ventures are more dependent on governmental incentives than other firms for making innovations in clean technology profitable (Tsoutsos & Stamboulis, 2005). This conjecture is supported by theoretical and empirical studies (Acemoglu, Aghion, Bursztyn, & Hemous, 2012; Aghion, Dechezleprêtre, Hemous, Martin, & Van Reenen, 2016). Thus, compared with other new technology ventures, factors such as public financial support and environmental regulations that enhance the profitability of clean technology might be of particular importance for Cleantech startups. This leads to the formulation of the fourth hypothesis that is tested in this paper

Hypothesis 4. *Cleantech startups are in general more dependent on various forms of public support compared with other entrants.*

In conclusion, the existing literature on Cleantech startups is limited in terms of systematic studies on these issues. A major obstacle is the lack of information from regularly recurring data collections that allows us to observe new ventures over time. By using the Mannheim Foundation Panel as the database for our study, we can provide new evidence on the capabilities and innovation outcomes of Cleantech startups using a longitudinal perspective.

[1]There is a growing number of studies focusing on environmentally friendly technologies that are based on the Community Innovation Survey or related data (see, for example Van Leeuwen & Mohnen, 2017, Veugelers, 2012), but they concern themselves almost exclusively with established companies and not with startups. Therefore, it is difficult to draw more profound conclusions about the particular prerequisites of Cleantech startups from these studies.

[2]Comprehensive reviews of this research are provided by Popp, Newell, and Jaffe (2010), Van Leeuwen and Mohnen (2017) and Wagner (2003). For more recent studies, see Ghosal, Stephan, and Weiss (2019) and Van Leeuwen and Mohnen (2017).

3 | EMPIRICAL APPROACH

Our choice to analyze Cleantech startups operating in Germany is motivated by the fact that green technology from Germany has been growing due to a high demand for Cleantech solutions developed in Germany and also due to governmental support. In 2016, Germany accounted for 14% of the world market share of the green tech global market.[3]

3.1 | Data and variables

The sample of new ventures for this study is obtained from the Mannheim Foundation Panel provided by the Centre for European Economic Research (ZEW; Gottschalk, 2013). This unique data set provides information regarding founders' individual characteristics, technological capabilities, and other specific characteristics of each venture. It also covers policy support and innovation outcomes. The panel data contains yearly information about new ventures founded during the years 2005–2015, and includes follow-up questions in subsequent years. Between 5,000 and 6,000, new firms covering most industries are added to the panel each year (ZEW, 2018). For the 2011 wave, questions for new entrants targeted environmental effects of firms' products and services, such as emission reduction, improved energy efficiency and better recyclability.[4] The new entrants' responses to this question in the 2011 wave allow us to classify 567 of the total 1,751 firms that answered this question as Cleantech. In the empirical analysis, we observe these startups over the period 2011–2014, and we use a cohort approach for defining a panel of new ventures.[5]

Table A1 in the Appendix presents a description of the variables used in our study. Our two main dependent variables are Inno and Novel. These are categorical variables and form the main focus of our study. We use a set of explanatory variables to perform our analyses, including: Startup characteristics, Technological capabilities (consisting of R&D and patents), Founder's characteristics (level of education, specialization of education and experience), Public support and Industry.

3.2 | Identification of a control group of non-Cleantech ventures

To the best of our knowledge this paper is the first study that uses PSM to analyze Cleantech startups by defining a comparison group of non-Cleantech startups with similar characteristics, in particular with regard to technological capabilities. Cleantech startups are defined as the treated group that we then match with non-Cleantech startups. Specifically, we apply PSM to match the 567 Cleantech startups with 567 non-Cleantech startups. Applying a matching approach enables us to compare outcomes of Cleantech and other startups conditional on similar characteristics (Rosenbaum & Rubin, 1984, 1985; Rubin, 1997). Previous studies have proven the effectiveness of PSM to investigate different types of startups, for example, academic spin-offs and nonacademic startups (Cantner & Goethner, 2011; Stephan, 2014).

The application of PSM methodology follows Gantumur and Stephan (2011) and Stephan (2014). Let C_i represent a dummy variable that indicates Cleantech for startup i, with $C_i = 1$ for "Cleantech" startups and $C_i = 0$ for "non-Cleantech" startups. Let X_i denote a set of observed covariates. Then, the propensity of belonging to $C_i \in \{0, 1\}$ is expressed conditional on X_i

$$p\,(C_i|X_i) = Pr\,(C_i = 1|X_i) = E\,(C_i|X_i), \tag{1}$$

which is obtained from a probit regression with C_i as the dependent variable.PSM enables us to analyze the difference between Cleantechs' and non-Cleantechs'. outcomes directly by using the conditional independence assumption.[6]

The average outcome of Cleantechs is defined as $E(I_{i1}|X_i,\ C_i = 1)$, and the average outcome of non-Cleantechs is defined as $E(I_{i0}|X_i,\ C_i = 0)$. The effect of being a Cleantech on the outcome variables can be estimated by using the difference of observed averages on those outcomes for the non-Cleantech controls[7]

$$\tau^e = E(I_{i1}|p_i, C_i = 1) – E(I_{i0}|p_i, C_i = 0), \tag{2}$$

where p_i is the propensity score determined by Equation (1).

Hypotheses 1 and 4 are analyzed from the PSM results by comparing averages of relevant variables between unmatched and matched samples and also by analyzing the significance of those variables in the underlying PSM probit model. **Hypotheses** 2 and 3 are tested by using probit regressions based on the matched cohorts.

Our first model tests **Hypothesis** 2 by using the binary variable DInno as the dependent variable and utilizing the matched sample. If the startup i has innovative products or services that are not based on common technology, but are a new combination of existing technology or self-developed new technology, this is denoted as DInno = 1. The specification for estimating the likelihood for DInno = 1|X in year t is

[3]https://www.greentech-rade-in-gerrany.de/en/environrental-technology-in-gerrany/, retrieved on June 4, 2019.

[4]The two relevant questions are (a) "Are there eco-credentials from using your product or service? Positive environmental impacts should be a central characteristic of your product or service." (b) "How do your products/service contribute to environment protection? Is this due to 1: improvement of energy efficiency, 2: production of renewable energy, 3: reduction of emissions in the field of air, water, soil, noise 4: improvement of reusability of products. Please tell if your product contributes in the mentioned area 1: no contribution, 2: yes, small contribution, 3: yes, medium contribution, 4: yes, high contribution"

[5]The panel is not balanced because firms might not be observed in later years. One reason is default in subsequent years. Another reason for panel attrition might be nonresponse in later years. Also some firms do not answer all questions. Studying the reasons for panel attrition is beyond the scope of this study. As long as attrition is not systematically different between Cleantech and non-Cleantech startups, and there is no indication of such a difference, attrition does not bias the results.

[6]This assumption basically states that selection into the Cleantech group after PSM is not related to observed characteristics (i.e., almost random), which implies that selection bias is not present.

[7]In the terminology of treatment effect analysis, this corresponds to the average treatment effect on the treated, where the control group serves as an estimate of the unobserved counterfactual that is "what average outcome would Cleantech firms have had if they had not been a Cleantech startup."

$$P\,(\text{DInno}_{it}) = f\,(\text{Cleantech}_i, \text{year}_t, \text{tech capabilities}_{it}, \text{founder characteristics}i, \text{startup characteristics}_i, \text{public support}_{it}). \quad (3)$$

Our second model tests **Hypothesis** 3 using the dependent variable DNovel that describes whether new venture *i* has launched a market novelty. The likelihood of DNovel = $1|X$ is given by

$$P\,(\text{DNovel}_{it}) = f\,(\text{Cleantech}_i, \text{year}_t, \text{tech capabilities}_{it}, \text{founder characteristics}i, \text{startup characteristics}_i, \text{public support}_{it}). \quad (4)$$

In both Equations (3) and (4), tech capabilities consists of the variables continuous R&D and patent. Founder characteristics is captured by founder's education background, founder's industry experience, founder's previous enterprise experience, founder's disciplinary background, for example, Economics/Business, Natural Sciences, and Engineering. Startup characteristics is defined by startup employees, foundation year, and industry sector. Finally, public support consists of the variables subsidized bank loan, grant/subsidy, state guarantees, public venture capital and other support.

To gain further insights, we also employ multinomial logit regression for Models (3) and (4), where we use Inno and Novel as categorical dependent variables indicating innovativeness and market novelties with more differentiated outcomes again by utilizing the matched sample. Dependent variable Inno describes different degrees of innovation, for example, Inno = 1 (applying common technology), Inno = 2 (new combination of existing technology), Inno = 3 (application of third party new technology), and Inno = 4 (self- developed technology). Dependent variable Novel consists of Novel = 1 (no market novelty), Novel = 2 (novelty in a regional market), Novel = 3 (novelty in Germany), and Novel = 4 (novelty in the world market).

4 | EMPIRICAL RESULTS

4.1 | Propensity score matching and balancing test results

The results of the probit estimation used to determine the propensity score of being a Cleantech startup are reported in Table A2. Based on the entire sample of 1,751 startups that answered the questions related to Cleantech in year 2011, these results show that founder's education with an early focus on the labor market (apprenticeship and vocational college), and an educational background in engineering are more likely to be observed for Cleantech startups. Technological and innovation capabilities are captured by variables Continuous R&D and Patent. Both variables are positive and significant, supporting **Hypothesis** 1 and indicating that Cleantech startups have, on average, higher capabilities relative to all other startups.

For simplicity, we perform 1:1 nearest neighbors PSM without replacement.[8] The descriptive statistics in Table A3 focus on the comparisons of Cleantech startup characteristics between the matched and unmatched samples. In the following analysis, we refer to the unmatched sample as "other startups" and to the matched sample of non-Cleantech as "control group" or simply as "non-Cleantech startups".

Table A3 demonstrates that after matching the differences between our treated (Cleantech) and the control (non-Cleantech) group are reduced compared with other startups (unmatched sample). The balancing assumption is confirmed for all independent variables, and the overall measures of covariate imbalance before and after matching are satisfactory (cf. Table A3 notes).[9]

The Industry experience variable is measured in years, where higher numbers reflect increasing experience. Without matching, the Industry experience of Cleantech founders is higher with about 15.35 years on average compared with 13.72 of founders of other startups. This indicates that the founders of Cleantech startups tend to have higher expertise due to the Cleantech founders' previous experiences in the industry. Nevertheless, the balancing assumption holds after matching, and leaves both groups with mean values of about 15 years.

About half of the Cleantech founders hold a professional qualification. The second and third most common degree held by a Cleantech startup founder is college/university and vocational college at 29% and 18%, respectively. Another founder-specific characteristic that may influence the success of establishing a Cleantech startup is a founder's background in engineering. Twenty-eight percent of Cleantech founders hold an engineering degree, whereas only 16% of founders of other startups have an engineering degree. Other university degrees (e.g., economics/business, natural sciences, math/computer, and humanities) are less frequent for the Cleantech founders. A small fraction (3.5%) of Cleantech founders does not have a formal educational degree.

In Table A3, our technological capabilities measures (Continuous R&D and Patent) reveal that it is more likely for Cleantech startups to hold patents and to conduct continuously R&D. Although 10.4% of Cleantech startups hold patents, the average percentage of other startups that hold patents is 5.3%, and the difference of Patent between Cleantech and other startups is statistically significant. For the matched sample, however, the balancing assumption holds and both groups are similarly likely to hold a patent. Furthermore, around 27% of Cleantech startups perform continuous R&D, whereas only around 23% of other startups conduct continuous R&D. This difference is not significant for unmatched and matched samples. With regard to the results for Patent, we can draw the conclusion that Cleantech startups have higher technological capabilities compared with other startups. This provides support for **Hypothesis** 1.

Cleantech startups are prevalent across industry sectors. Table A3 reveals that 26.3% of Cleantech ventures belong to technology-

[8] The PSM assumption of common support, that is, an overlap of propensity scores between treated and controls, is confirmed by the results.

[9] As further robustness tests, we changed the matching method to a caliper with defined radius, dropped the noreplacement option, tested kernel matching, and used covariance-based Mahalanobis matching. Despite the commonly observed trade-off between bias reduction and variance (see Table A1, Caliendo & Kopeinig, 2008), the main results are robust with respect to the chosen matching procedure.

intensive industries. The second largest industry sector is the skill-intensive service sector comprising 13% of Cleantech startups. The third and fourth most common industry sectors by percentage average are high-tech manufacturing and other business-oriented services, respectively. The remaining industry sectors, for example, cutting-edge tech manufacturing, and software sectors constitute less than 5% each.

We find that 31% of Cleantech startups receive public support through Grant/Subsidy, whereas 30% of the other startups receive Grant/Subsidy. This statistically not significant difference indicates that both Cleantech and other new ventures have similar access to Grant/Subsidy. It does, however, appear that Cleantech startups are more likely to have access to other types of nonfinancial support. Fifteen percent of Cleantech startups receive Other support, whereas only 12% of other startups receive this support. Other categories of access to finance for Cleantech startups, for example, subsidized bank loans, state guarantees, and public venture capital comprises 5.5%, 4.4%, and 0.5%, respectively. One surprising finding is that the percentage of Cleantech startups that receive subsidized bank loans is significantly lower compared with other startups that is not in line with **Hypothesis** 4. Note, however, that differences in all public support variables between Cleantech and non-Cleantech startups equalize after matching.

4.2 | Results for Cleantech startups' entrepreneurial orientation

In order to address the relevance of entrepreneurial opportunity, we investigate the entrepreneurial strategy of Cleantech startups by drawing comparisons with the control group's entrepreneurial strategy. This analysis is based on the matched sample of Cleantech and non-Cleantech ventures that answered the entrepreneurial orientation question in the 2014 survey.[10] The results for entrepreneurial orientations of the matched sample are shown in Tables A4 and A5.

Table A4 reports that about 46% of Cleantech startups opt for a business strategy that focuses completely on marketing of tried-and-true products or services (Strategy A). A majority of non-Cleantech startups also adopt a marketing of tried-and-true products or services as a business orientation. We can also see that around 25% of Cleantech startups follow a business strategy that emphasizes innovation, technological leadership, and R&D (*Strategy B*), whereas only 17.5% of non-Cleantech startups focus on this strategy. Thus, Cleantech startups are more likely to follow a dedicated strategy in innovation, technological leadership, and R&D (Strategy B), which provides support for **Hypothesis** 2. Note also that the differences between Cleantech and controls are statistically significant.

Based on information provided in Table A5, the majority of Cleantech and non-Cleantech ventures select *totally A* (i.e., changes of a minor nature rather than of a fundamental and radical nature), as their strategy for product improvement or changes in product or service lines. This implies that both groups show a strong preference for incremental product improvement. However, about 20% of Cleantech ventures select *totally B* as their product improvement strategy, which is higher compared to non-Cleantech startups where only 13% indicated this strategy. This result is line with the existing literature, which suggests that green firms show a stronger preference for radical improvement as a strategy, thereby showing their commitment to improving the environment (Dangelico, 2017; Shu et al., 2016).

The information presented in Tables A4 and A5 hints at the heterogeneous strategies that Cleantech startups employ in order to realize entrepreneurial opportunities and to meet the growing consumer demand for green products. A study by Nemet (2009) on the wind power industry emphasizes that rapid technical change does not respond well to demand-pull. At the same time, however, nonincremental technical change is driven by technological-push (Dosi, 1988; Nemet, 2009). These two seemingly contradictory pull/push forces are particularly dynamic in the environmental technology sector where there is a pressing need for nonincremental technical change as businesses globally struggle to meet climate goals set by policymakers. Although the impact of Cleantech sectors might still be minor, our matched sample analysis indicates that Cleantech startups have a higher likelihood of concentrating on innovation and technological leadership as their business strategy and are more likely to focus on a radical product improvement than non-Cleantech startups. This evidence supports **Hypothesis** 2, which states that Cleantech ventures are more likely to develop own technology of a cutting-edge character.

4.3 | Results for the innovation-related outcome variables

We devote this subsection to presenting the descriptive statistics of our innovation outcome variables for both Cleantech and non-Cleantech startups in the matched sample over the period 2011-2014. The two outcome variables we analyze in this subsection are introduction of market novelties and innovation degree of new products or services. Based on the information provided in Table A6, 16.5% of Cleantech ventures and 11.8% of non-Cleantech ventures possess market novelties. Table A6 also reveals that Cleantech startups are more likely to generate market novelties in regional, national, and world markets when compared with non-Cleantech ventures, which supports **Hypothesis** 3.

Table A7 reports descriptive statistics for the innovation degree of products and services for the Cleantech cohort and the control group. Clearly, we observe that Cleantech startups develop products with varying innovation degrees. Whereas 26% of Cleantech startups introduce new products or services that utilize self-developed new technology, only 22.7% of non-Cleantech startups develop new technology. This evidence supports **Hypothesis** 2. However, 34.5% of Cleantech startups rely on combining existing technologies in a novel way, and is the most common type of innovation for new products or services.

[10]Due to panel attrition from year 2011–2014, the sample size reported in Tables A4 and A5 is lower compared with the initial sample size of 567 Cleantech and 567 non-Cleantech in the matched sample.

4.4 | Regression results

This subsection discusses the results of our four regression models. Table A8 reveals the results of marginal effects for our probit models based on the matched sample over the period 2011–2014. Variable Novel is the dependent variable for the probit regression in the first column and has a value of 1 if the startup has introduced market novelties and 0 if otherwise. Variable Inno in the second column denotes the innovation degree of products or services and has a value of 1 if the products are *not* based on common technology, and is 0 if otherwise.

The two probit regression models reveal that Continuous R&D and Patent are important drivers for both innovation outcome variables as the coefficients of Continuous R&D and Patent are significant at the 1% level. This implies that R&D and technological capabilities enhance the innovation outcomes of new ventures. The Cleantech dummy in both probit regressions is significant, suggesting that Cleantech ventures have a higher likelihood of generating innovation outcome compared to non-Cleantech startups. Our results are in line with earlier work by Horbach (2008), who suggests that eco-innovation is driven by improvements in technological capabilities. Based on the first probit regression, the probability of having introduced market novelties increases by 2.3% when the new venture belongs to the Cleantech group, which is significant at the 10% level. Thus, **Hypothesis** 3 is supported once again. Furthermore, the probability of Cleantech startups having products or services that incorporate technology beyond common technology is 11.5% higher than that of non-Cleantech ventures. The Cleantech coefficient in the second probit regression is even significant at a 1% level. This evidence strongly supports **Hypothesis** 2.

To shed further light on more detailed nuances, we now define Inno as a categorical variable instead of a binary variable. Table A9 displays marginal effects for the multinomial logit regression with Inno as the dependent variable. The lowest innovation degree (i.e., applying common technology), is defined as the base level for the multinomial logit model. The marginal effect of the Cleantech variable is significant and positive for most categories, except for self-developed new technology, which weakens the previously presented evidence regarding **Hypothesis** 2. However, because degrees of freedom are lower for this multinomial model, it might reduce the power of the test.

The likelihood of utilizing new combinations of existing technology or applying third party new technology increases by 7.8% and 4.2%, respectively, when the startup is from the Cleantech cohort. Furthermore, the Cleantech marginal effect of the base level of the multinomial logit regression is significant and negative, implying that Cleantech startups are in general more likely to use novel technologies compared the non-Cleantech controls. It is also worth noting that the marginal effect of Cleantech is the highest for the category where existing technology is used and combined in an innovative way.

The results presented in Table A9 also indicate that Continuous R and D increases the probability of both Cleantech and non-Cleantech ventures having self-developed technology by 21%. Furthermore, new ventures that hold a patent have a 12.5% higher likelihood to develop own technology, which is significant at the 1% level. Combining existing technology in a novel way or applying third party new technology is not affected by Patent, which is in line with a priori expectation.

The variables Grant/Subsidy, State guarantees, and Other support are significant at 5%, 10%, and 10%, respectively, and positively related with the application of third party new technology. This implies that access to governmental support is an important driver for applying third party new technology. Access to Grant/Subsidy, State guarantees, and Other support increase the chance of applying third party new technology for products or services by 6.2%, 15%, and 7.2%, respectively.

Table A9 also reports that self-developed new technology is driven by a startup's technological capabilities, the founder's natural sciences background, and the founder's experience in having previously established an enterprise. As discussed earlier, both Continuous R&D and Patent as technological capabilities measures are considered to be crucial resources that influence a higher degree of innovation among startups. Not surprisingly, another essential capability that generates a higher innovation degree is the founder's natural sciences background. The likelihood of having self-developed new technology increases by 13.5% when the founder of a startup holds a degree in natural sciences. Table A9 reveals that the Founder previous enterprise coefficient is significant at 5% level and increases the chance of having self-developed technology by 5.8%.

The last results worthy of note concerns the multinomial regression estimations for the variable Novel. This categorical variable indicates whether market novelties have been introduced in the regional, national (German), or world markets. Based on the results presented in Table A10, the Cleantech dummy is significant and positively related to market novelties in the regional market. Cleantechs are 2.4% more likely to generate novelties in the regional market, but are not more likely than their peers to have novelties in either the German or the world market.

Table A10 also provides evidence that the introduction of novel products or services in the world market is positively affected by technological capabilities measures (e.g., Continuous R&D, Patent), as well as by the founder's educational background in Economics/Business and in Natural Sciences that are significant at the 5% and 10% level, respectively. Technological capabilities measures are also essential factors that trigger startups to create new products in novel ways (see Section 4.1). Table A10 highlights that technological capabilities, reflected as Continuous R&D, are important for startups to create market novelties at the world market scale. The variable Continuous R&D increases the likelihood of having launched a novelty on the world market by almost 12%, whereas variable Patent increases the likelihood of introducing such a world market novelty by 5.2%.

5 | SUMMARY AND CONCLUSIONS

The growing demand for green products and services has provided an entrepreneurial opportunity for new business ventures in the growing sector of developing and applying technologies that are cleaner and conserve more energy and resources. This study analyzes the innovation capabilities, entrepreneurial opportunities, and outcomes of startups in Cleantech. The analysis is performed by using data from the Mannheim Foundation Panel to identify a group of 567 Cleantech startups. By applying PSM, we determine a control group of 567 non-Cleantech startups with similar characteristics. This first step of the analysis reveals significant differences of technological and innovation capabilities between Cleantech startups and other startups. We then use regression models to analyze and compare the innovation outcomes of Cleantech and the control group startups over the period 2011–2014.

To the best of our knowledge, this is the first study that incorporates Cleantech startups' opportunities, capabilities, and innovation using a comprehensive and detailed firm-level panel data set allowing for a comparison between new Cleantech ventures and entrants from other sectors. Our most important contribution to the existing literature is to show that Cleantech ventures have, on average, higher technological and innovation capabilities compared with other startups. Our regression models show that Cleantech startups tend to combine existing technology in a novel way but are not more likely than their control group peers to provide self-developed new technology. Our analysis does indicate, however, that Cleantech ventures are overall more likely to introduce market novelties in subsequent years, albeit mainly in the regional market, rather than the national or global market. This implies that the innovation content of Cleantech market novelties is mainly incremental and not of a radical character.

There are a number of salient factors that determine the high degree of a Cleantech startup's technological capabilities, in particular a focus on continuous R&D and holding patents. In addition to this, the venture's business strategy and the characteristics of the founder, be it educational background or previous entrepreneurial experience, also play a significant role. We expected that public support might be decisive for stimulating Cleantech venture growth. However, the analysis reveals that Cleantech new ventures do not rely more on governmental grants than the control group. Nevertheless, Cleantech startups are more likely to receive certain forms of nonfinancial public support. Whether public procurement, energy prices and taxes, or environmental regulation is the most effective instrument for fostering the sector of new Cleantech ventures, is an open question left for future research.

ORCID

Febi Jensen https://orcid.org/0000-0001-9707-4847
Hans Lööf https://orcid.org/0000-0002-5871-8571
Andreas Stephan https://orcid.org/0000-0001-5776-9396

REFERENCES

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American Economic Review*, *102*(1), 131–166. https://doi.org/10.1257/aer.102.1.131

Acs, Z. J., & Audretsch, D. B. (2003). Innovation and technological change. In *Handbook of entrepreneurship research* (pp. 55–79). Springer.

Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy*, *124*(1), 1–51. https://doi.org/10.1086/684581

Almus, M., & Nerlinger, E. A. (1999). Growth of new technology-based firms: Which factors matter? *Small Business Economics*, *13*(2), 141–154. https://doi.org/10.1023/A:1008138709724

Amankwah-Amoah, J., Danso, A., & Adomako, S. (2019). Entrepreneurial orientation, environmental sustainability and new venture performance: Does stakeholder integration matter? *Business Strategy and the Environment*, *28*(1), 79–87. https://doi.org/10.1002/bse.2191

Baum, C. F., Lööf, H., & Nabavi, P. (2019). Innovation strategies, external knowledge and productivity growth. *Industry and Innovation*, *26*(3), 348–367. https://doi.org/10.1080/13662716.2018.1499502

Bertoni, F., Colombo, M. G., & Grilli, L. (2011). Venture capital financing and the growth of high-tech start-ups: Disentangling treatment from selection effects. *Research Policy*, *40*(7), 1028–1043. https://doi.org/10.1016/j.respol.2011.03.008

Bjornali, E. S., & Ellingsen, A. (2014). Factors affecting the development of clean-tech start-ups: A literature review. *Energy Procedia*, *58*, 43–50. Renewable Energy Research Conference, RERC 2014. http://www.sciencedirect.com/science/article/pii/S1876610214017743, https://doi.org/10.1016/j.egypro.2014.10.407

Bloom, N., & Van Reenen, J. (2011). Human resource management and productivity. In *Handbook of labor economics* (Vol. 4) (pp. 1697–1767). Elsevier.

BMUB (2014), Greentech made in Germany 4.0. Environmental technology atlas for Germany, Technical report, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

Caliendo, M., & Kopeinig, S. (2008). Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys*, *22*(1), 31–72. https://doi.org/10.1111/j.1467-6419.2007.00527.x

Cantner, U., & Goethner, M. (2011). Performance differences between academic spin-offs and non-academic start-ups: A comparative analysis using a non-parametric matching approach. In *Paper presented at the DIME final conference* (Vol. 6) (p. 8).

Cefis, E., & Orsenigo, L. (2001). The persistence of innovative activities: A cross-countries and cross-sectors comparative analysis. *Research Policy*, *30*(7), 1139–1158. https://doi.org/10.1016/S0048-7333(00)00139-6

Dangelico, R. M. (2017). What drives green product development and how do different antecedents affect market performance? A survey of Italian companies with eco-labels. *Business Strategy and the Environment*, *26*(8), 1144–1161. https://doi.org/10.1002/bse.1975

Dechezleprêtre, A., Martin, R. and Mohnen, M. (2014), Knowledge spillovers from clean and dirty technologies, CEP Discussion Papers dp1300, Centre for Economic Performance, LSE. **URL:** https://ideas.repec.org/p/cep/cepdps/dp1300.html

Doran, J., & Ryan, G. (2016). The importance of the diverse drivers and types of environmental innovation for firm performance. *Business Strategy and the Environment*, *25*(2), 102–119. https://doi.org/10.1002/bse.1860

Dosi, G. (1988). Sources, procedures, and microeconomic effects of innovation. *Journal of Economic Literature*, 1120–1171.

Eyraud, L., Clements, B., & Wane, A. (2013). Green investment: Trends and determinants. *Energy Policy*, *60*, 852–865. https://doi.org/10.1016/j.enpol.2013.04.039

Gantumur, T., & Stephan, A. (2011). Mergers & acquisitions and innovation performance in the telecommunications equipment industry. *Industrial and Corporate Change*, *21*(2), 277–314.

Ghosal, V., Stephan, A., & Weiss, J. F. (2019). Decentralized environmental regulations and plant-level productivity. *Business Strategy and the Environment*, *28*(6), 998–1011. https://doi.org/10.1002/bse.2297

Gilbert, B. A., McDougall, P. P., & Audretsch, D. B. (2006). New venture growth: A review and extension. *Journal of Management*, *32*(6), 926–950. https://doi.org/10.1177/0149206306293860

Giudici, G., Guerini, M., & Rossi-Lamastra, C. (2017). The creation of cleantech startups at the local level: The role of knowledge availability and environmental awareness. *Small Business Economics*, 1–16.

Gottschalk, S. (2013), The Research Data Centre of the Centre for European Economic Research (ZEW-FDZ), *ZEW Discussion Papers* 13-051, ZEW—Leibniz Centre for European Economic Research. **URL:** https://EconPapers.repec.org/RePEc:zbw:zewdip:13051

Horbach, J. (2008). Determinants of environmental innovation—new evidence from german panel data sources. *Research Policy*, *37*(1), 163–173. https://doi.org/10.1016/j.respol.2007.08.006

Jantunen, A., Puumalainen, K., Saarenketo, S., & Kyläheiko, K. (2005). Entrepreneurial orientation, dynamic capabilities and international performance. *Journal of International Entrepreneurship*, *3*(3), 223–243. https://doi.org/10.1007/s10843-005-1133-2

Klette, T. J., & Kortum, S. (2004). Innovating firms and aggregate innovation. *Journal of Political Economy*, *112*(5), 986–1018. https://doi.org/10.1086/422563

Malen, J., & Marcus, A. A. (2017). Promoting clean energy technology entrepreneurship: The role of external context. *Energy Policy*, *102*, 7–15. https://doi.org/10.1016/j.enpol.2016.11.045

Nemet, G. F. (2009). Demand-pull, technology-push, and government-led incentives for non-incremental technical change. *Research Policy*, *38*(5), 700–709. https://doi.org/10.1016/j.respol.2009.01.004

Pernick, R., & Wilder, C. (2007). *The clean tech revolution: The next big growth and investment opportunity*. Collins.

Peters, B. (2009). Persistence of innovation: Stylised facts and panel data evidence. *The Journal of Technology Transfer*, *34*(2), 226–243. https://doi.org/10.1007/s10961-007-9072-9

Popp, D., Newell, R. G., & Jaffe, A. B. (2010). Energy, the environment, and technological change. In *Handbook of the economics of innovation* (Vol. 2) (pp. 873–937). Elsevier. https://doi.org/10.1016/S0169-7218(10)02005-8

Porter, M. E., & Van der Linde, C. (1995). Toward a new conception of the environment–competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97–118. https://doi.org/10.1257/jep.9.4.97

Rehfeld, K.-M., Rennings, K., & Ziegler, A. (2007). Integrated product policy and environmental product innovations: An empirical analysis. *Ecological Economics*, *61*(1), 91–100. https://doi.org/10.1016/j.ecolecon.2006.02.003

Romijn, H., & Albaladejo, M. (2002). Determinants of innovation capability in small electronics and software firms in Southeast England. *Research Policy*, *31*(7), 1053–1067. https://doi.org/10.1016/S0048-7333(01)00176-7

Rosenbaum, P. R., & Rubin, D. B. (1984). Reducing bias in observational studies using subclassification on the propensity score. *Journal of the American Statistical Association*, *79*(387), 516–524. https://doi.org/10.1080/01621459.1984.10478078

Rosenbaum, P. R., & Rubin, D. B. (1985). Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician*, *39*(1), 33–38.

Rubin, D. B. (1997). Estimating causal effects from large data sets using propensity scores. *Annals of Internal Medicine*, *127*(8_Part_2), 757–763. https://doi.org/10.7326/0003-4819-127-8_Part_2-199710151-00064

Sæther, B., & Amundsen, A. (1996). Cleaner production assessment in Norway: Experiences and policy implications. *Business Strategy and the Environment*, *5*(3), 178–187. https://doi.org/10.1002/(SICI)1099-0836(199609)5:3<178::AID-BSE62>3.0.CO;2-M

Sáez-Martínez, F. J., Díaz-García, C., & Gonzalez-Moreno, A. (2016). Firm technological trajectory as a driver of eco-innovation in young small and medium-sized enterprises. *Journal of Cleaner Production*, *138*, 28–37. https://doi.org/10.1016/j.jclepro.2016.04.108

Shu, C., Zhou, K. Z., Xiao, Y., & Gao, S. (2016). How green management influences product innovation in China: The role of institutional benefits. *Journal of Business Ethics*, *133*(3), 471–485. https://doi.org/10.1007/s10551-014-2401-7

Stephan, A. (2014). Are public research spin-offs more innovative? *Small Business Economics*, *43*(2), 353–368. https://doi.org/10.1007/s11187-013-9539-z

Tang, M., Walsh, G., Lerner, D., Fitza, M. A., & Li, Q. (2018). Green innovation, managerial concern and firm performance: An empirical study. *Business Strategy and the Environment*, *27*(1), 39–51. https://doi.org/10.1002/bse.1981

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning*, *43*(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

Triebswetter, U., & Wackerbauer, J. (2008). Integrated environmental product innovation in the region of munich and its impact on company competitiveness. *Journal of Cleaner Production*, *16*(14), 1484–1493. https://doi.org/10.1016/j.jclepro.2007.09.003

Tsoutsos, T. D., & Stamboulis, Y. A. (2005). The sustainable diffusion of renewable energy technologies as an example of an innovation-focused policy. *Technovation*, *25*(7), 753–761. https://doi.org/10.1016/j.technovation.2003.12.003

Van Leeuwen, G., & Mohnen, P. (2017). Revisiting the Porter hypothesis: An empirical analysis of green innovation for the Netherlands. *Economics of Innovation and New Technology*, *26*(1–2), 63–77. https://doi.org/10.1080/10438599.2016.1202521

Veugelers, R. (2012). Which policy instruments to induce clean innovating? *Research Policy*, *41*(10), 1770–1778. https://doi.org/10.1016/j.respol.2012.06.012

Wagner, M. (2003). *The Porter hypothesis revisited: A literature review of theoretical models and empirical tests*. CSM.

York, J. G., & Venkataraman, S. (2010). The entrepreneur–environment nexus: Uncertainty, innovation, and allocation. *Journal of Business Venturing*, *25*(5), 449–463. https://doi.org/10.1016/j.jbusvent.2009.07.007

ZEW (2018), Scientific-Use-Files KfW/ZEW Start-up Panel and Mannheim Start-Up Panel—Documentation of the anonymization process. ZEW—Leibniz Centre for European Economic Research.

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APPENDIX A

TABLE A1 Definitions of variables used in this study

Variables	Descriptions
Cleantech	A dummy variable 1 represents new ventures in Cleantech 0 denotes new ventures in non-Cleantech
Dependent variables	
Inno	A categorical variable that describes different degrees of innovation, only available for selected industries[a] 1 represents tested and commonly used techniques 2 represents a new combination of old or established techniques 3 represents new products and services that incorporate application of third party new technology 4 represents new products and services that apply self-developed new technology
Novel	A categorical variable that represent having market novelties 1 represents having no market novelty 2 represents market novelty in the regional market 3 represents market novelty in the German market 4 represents market novelty in the world market
Startup characteristics	
Foundation year	Foundation year of startup
Founding team	1 describes team-foundation 0 single founder
Startup has employees	1 describes startup has at least one employee in founding year 0 no employees in founding year
Tech capabilities	
Continuous R&D	1 represents continuous R&D. 0 no continuous R&D
Patent	1 enterprise has at least one valid patent 0 no valid patents
Founders' characteristics	
Founder qualification	A categorical variable that represents highest education qualification of founders 1 represents founders with no formal degree 2 represents founders with apprenticeship/professional qualification 3 represents founders with vocational college degree/master craftsman 4 represents founders with college/university degree
Economics/Business	1 represents founders who have economics/business degree from college/university 0 otherwise 0 otherwise
Engineering	1 describes founders who have engineering degree from college/university. 0 otherwise
Math/Computer Science	1 describes founders who have mathematics or computer sciences degree from college/university 0 otherwise
Humanities	1 describes founders who have a degree within humanities from college/university. 0 otherwise
Founder industry experience	Founders' industry experience in years 1 represents founders with $\leq$3 years experience 2 represents founders with <3 × $\leq$7 years of experience 3 represents founders with <7 × $\leq$14 years of experience 4 represents founders with <14 × $\leq$21 years of experience 5 represents founders with $\leq$21 × $\leq$32 years of experience 6 represents founders with >32 years of experience
Founder previous enterprise	1 if one of the founders has established an enterprise before

(Continues)

TABLE A1 (Continued)

Variables	Descriptions
	0 otherwise
Public support	A categorical variable that represents financing types that new ventures receive
Public support	0 no support 1 represents subsidized bank loan 2 represents grant/subsidy 3 represents state guarantees 4 represents financing from public venture capital 5 represents other nonfinancial support
Industry	Classification of industry based on WZ2008 code
Cutting-edge technology manufacturing	20.20, 21.10, 21,20, 24.46, 25.40, 26.11,26.20, 26.30, 26.40, 26.51, 26.60, 30.30,30.40, 32,50
High-technology manufacturing	20.13, 20.14, 20.16, 20.17, 20.41, 20.51, 20.53, 20.59, 22.11, 22.19, 23.19, 26.70, 27.11, 27.12, 27.20, 27.40, 27.90, 28.11–15, 28.23, 28.24, 28.29, 28.30, 28.41,28.49, 28.92–96, 28.99, 29.10, 29.31, 29.32, 30.20
Technology-intensive services	61.1–3, 62 (without 62.01), 63.1, 71.1–2, 72.1
Software	62.01
Skill-intensive services	69.1–2, 70.2, 72.2, 73.1–2
Business-oriented services	49.2, 49.5, 50.2, 50.4, 51.2, 52, 53, 61.9, 63.9, 64, 74.1, 74.3–9, 77.1, 77.3–4, 78, 80–82

[a]Variable Inno is available for the following industries: Cutting-edge technology manufacturing, High-technology manufacturing, Technology-intensive services, Software, and other manufacturing.

TABLE A2 Probit model for determining propensity score, dependent variable is likelihood of being a Cleantech startup

Prob(Cleantech = 1)	
Startup characteristics	
Founding team = 1	0.055 (0.69)
Technological characteristics	
Continuous R&D = 1	0.163* (1.85)
Patent = 1	0.383*** (2.91)
Founder characteristics	
Founder industry experience = 1	0.001*** (2.93)
Founder previous enterprise = 1	0.085 (1.16)
Startup has employees = 1	−0.010 (0.16)
Economics/Business = 1	−0.190 (1.41)
Natural Sciences = 1	0.250 (1.49)
Engineering = 1	0.533*** (4.11)
Math/Computer Science = 1	−0.289 (1.49)
Humanities = 1	0.067 (0.45)
Founder qualification[a]	
Apprenticeship/Professional school = 1	0.464** (2.08)
Vocational College/Master craftsman = 1	0.394*** (2.62)
College/University degree = 1	0.114 (1.05)
Public support	
Subsidized bank loan = 1	−0.318*** (2.33)
Grant/Subsidy = 1	0.044 (0.56)
State guarantees = 1	0.031 (0.20)
Public venture capital = 1	−0.206 (0.50)
Other support = 1	0.132 (1.28)
Industry	
Cutting-edge technology manufacturing	−0.782*** (5.58)
High-tech manufacturing	0.293* (1.95)
Technology-intensive services	0.076 (0.79)
Software	−0.602*** (4.21)
Skill-intensive services	−0.302*** (2.98)
Business-oriented services	0.055 (0.43)
N	1,751

Note. *t* statistics in parentheses.

[a]ref cat: no formal degree.

$^{*}p < .10$. $^{**}p < .05$. $^{***}p < .01$.

TABLE A3 Difference of characteristics between Cleantech and non-Cleantech startups of unmatched (U) and matched (M) samples

Variables		Cleantech =1 Mean	=0 Mean	%bias	% reduct bias	t-value	p > t
Founding team = 1	U	0.314	0.313	0.1		0.02	0.98
	M	0.314	0.291	4.9	−3796.7	0.84	0.40
Founder qualification							
No formal degree	U	0.035	0.034	0.8		0.16	0.87
	M	0.035	0.032	1.9	−136.8	0.33	0.74
Founder apprenticeship	U	0.504	0.476	5.6		1.10	0.27
	M	0.504	0.520	−3.2	43.4	−0.53	0.59
Founder vocational college	U	0.178	0.161	4.5		0.88	0.38
	M	0.178	0.179	1.4	68.5	0.23	0.81
Founder College/ University	U	0.282	0.328	−10.1		−1.96	0.05
	M	0.282	0.275	1.5	84.8	0.26	0.79
Founder industry experience = 1	U	15.35	13.72	16.2		3.21	0.00
	M	15.35	15.21	1.4	91.4	0.23	0.82
Founder previous enterprise = 1	U	0.421	0.392	6.0		1.18	0.24
	M	0.421	0.418	0.7	88.1	0.12	0.90
Startup has employees = 1	U	0.592	0.583	1.8		0.5	0.62
	M	0.592	0.584	1.8	1.8	1.08	0.28
Patent = 1	U	0.104	0.053	19.0		3.93	0.00
	M	0.104	0.078	9.9	48.0	1.55	0.12
Continuous R and D = 1	U	0.273	0.238	8.1		1.59	0.11
	M	0.273	0.245	6.5	19.8	1.08	0.28
Economics/ Business = 1	U	0.097	0.179			−4.49	0.00
	M	0.097	0.107	−3.1	87.1	−0.59	0.56
Natural Science = 1	U	0.05996	0.05659	1.4		0.28	0.77
	M	0.05996	0.04938	4.5	−213.4	0.78	0.43
Engineering Science = 1	U	0.27866	0.16385	27.9		5.66	0.00
	M	0.27866	0.26984	2.1	92.3	0.33	0.74
Mathematics/Computer Science = 1	U	0.025	0.067	−20.5		−3.74	0.00
	M	0.025	0.0194	2.5	87.7	0.61	0.54
Humanities = 1	U	0.06702	0.09797	−11.3		−2.14	0.03
	M	0.06702	0.0582	3.2	71.5	0.61	0.54
Industry							
Cutting-edge manufacturing	U	0.049	0.106	−21.4		−3.96	0.00
	M	0.049	0.042	2.6	87.6	0.57	0.57
High-tech manufacturing	U	0.101	0.039	24.4		5.17	0.00
	M	0.101	0.076	9.8	60.0	1.47	0.14
Technology- intensive services	U	0.264	0.178	21.1		4.24	0.00
	M	0.264	0.266	−0.4	98.0	−0.07	0.95
Software	U	0.049	0.125	−27.0		−4.96	0.00
	M	0.049	0.048	0.6	97.7	0.14	0.89
Skill-intensive services	U	0.129	0.181	−14.6		−2.80	0.00
	M	0.129	0.134	−1.5	90.0	−0.26	0.79
Business-oriented services	U	0.079	0.071	3.2		0.63	0.59
	M	0.079	0.079	0.0	100.0	0.00	1.00
Public support							
Subsidized bank loan	U	0.055	0.086	−12.3		−2.33	0.02
	M	0.055	0.044	4.1	66.4	0.82	0.41
Grant/Subsidy	U	0.310	0.298	2.7		0.52	0.60

(Continues)

TABLE A3 (Continued)

Variables		Cleantech =1 Mean	=0 Mean	%bias	% reduct bias	t-value	p > t
	M	0.310	0.298	2.7	−0.7	0.45	0.65
State guarantees	U	0.048	0.047	0.2		0.03	0.97
	M	0.048	0.042	2.5	−1544.4	0.43	0.67
Public VC	U	0.005	0.008	−3.8		−0.72	0.47
	M	0.005	0.009	−4.3	−11.8	−0.71	0.48
Other support	U	0.148	0.117	9.1		1.81	0.07
	M	0.148	0.145	1.0	88.5	0.17	0.87

Note. U = unmatched, M = matched sample. This Table is based on 567 Cleantech startups, the full sample of 1,184 non-Cleantech startups (U), and the matched sample of 567 non-Cleantech controls (M). Overall measures of covariate imbalance: pseudo R^2 from probit estimation, before matching (U): .118, *p*-value .000, after matching (M): 0.02, *p*-value .120, reduction in mean bias: 14.9 (U), 6.0 (M).

TABLE A4 Entrepreneurial orientation of Cleantech and non-Cleantech matched cohorts in year 2014. Strategy A represents marketing of tried-and-true products or services. Strategy B represents innovation, technological leadership, and R&D

Entrepreneurial Orientation Tried-and-true (A) versus technological leadership (B)		Cleantech =0	 =1	Total
Totally A	obs	102	108	210
	%	52.6	52.6	49.2
Preferably A	obs	22	22	45
	%	11.3	9.9	10.5
Undecided	obs	23	28	51
	%	11.9	12.0	11.9
Preferably B	obs	13	15	28
	%	6.7	6.4	6.6
Totally B	obs	34	59	93
	%	17.5	25.3	21.8
Total	obs	194	233	427
	%	100	100	100
Pearson chi2(4) = 4.019				Pr = 0.403

Note. *Cleantech* = 0 denotes non-Cleantech and *Cleantech* = 1 indicates Cleantech startups. The second row reports the relative frequency of each type of entrepreneurial orientation for each group.Abbreviation: obs, observations.

TABLE A5 Entrepreneurial orientation of Cleantech and non-Cleantech startups for matched cohorts answered in year 2014. Strategy A represents incremental product improvement. Strategy B represents extensive, fundamental (radical) product improvement

Entrepreneurial Orientation: Incremental (A) versus radical product improvement (B)		*Cleantech* =0	 =1	Total
Totally A	obs	95	125	220
	%	47.7	53.4	50.8
Preferably A	obs	44	27	71
	%	22.1	11.5	16.4
Undecidedly	obs	22	27	49
	%	11.1	11.5	11.3
Preferably B	obs	8	8	16
	%	4.0	3.4	3.7
Totally B	obs	30	47	77
	%	13.1	20.1	17.8
Total	obs	199	234	433
	%	100	100	100
Pearson chi2(4) = 9.66				Pr = 0.047

Note. *Cleantech* = 0 denotes non-Cleantech and *Cleantech* = 1 indicates Cleantech startups. The second row reports the relative frequency of each type of entrepreneurial orientation for each group.Abbreviation: obs, observations.

TABLE A6 Descriptive statistics for having market novelties from Cleantech and non-Cleantech startups after matching over the period 2011–2014

Variable Novel		Cleantech		Total
		0	1	
No market novelties	obs	1,276	1,273	2,549
	%	88.2	83.5	85.8
Regional market novelties	obs	27	66	93
	%	1.9	4.3	3.1
German market novelties	obs	67	94	161
	%	4.6	6.2	5.4
World market novelties	obs	77	91	168
	%	5.3	6.0	5.7
Total	obs	1,447	1,524	2,971
	%	100	100	100
Pearson chi2(3) = 20.0				Pr = 0.000

Note. Market novelty (Novel) represents the introduction of new products into the market. *Cleantech* = 0 denotes the non-Cleantech and *Cleantech* = 1 indicates the Cleantech startups. The second row reports the relative frequency of each type of market novelty for each group. Novel = 1 represents no market novelty. Novel = 2 represents novelty in the regional market. Novel = 3 denotes novelty in national market, Novel = 4 denotes novelty in the world market.Abbreviation: obs, observations.

TABLE A7 Descriptive statistics of innovation degree of new products/services for Cleantech and non-Cleantech startups after matching over the period 2011–2014

Variable Inno		Cleantech		Total
		=0	=1	
Common technology	obs	146	113	259
	%	37.2	23.4	29.6
New combination of existing technology	obs	108	166	274
	%	27.5	34.4	31.3
Application of third party new technology	obs	50	80	130
	%	12.7	16.6	14.9
Self-developed new technology	obs	89	123	212
	%	22.7	25.5	24.2
Total	obs	393	482	875
	%	100	100	100
Pearson chi2(3) = 20.0				Pr = 0.000

Note. Innovation degree (Inno) represents the innovation degree of new products/services. Data is only available for selected sectors, see Table A1. *Cleantech* = 0 denotes non-Cleantech and *Cleantech* = 1 indicates Cleantech startups. The second row reports the relative frequency of the innovation degree for each group. Inno = 1 denotes testing common techniques, Inno = 2 denotes new combination of common techniques, Inno = 3 denotes third party's new techniques, Inno = 4 denotes self-developed new techniques.

Abbreviation: obs, observations.

TABLE A8 Marginal effects for market novelties and innovation degree of new product or service, probit models Equations (3) and (4), Cleantech (treated) and non-Cleantech (control) startups for matched cohorts over the period 2011–2014

	prob (DNovel = 1), dy/dx	prob (DInno = 1), dy/dx
Cleantech	0.023* (1.82)	0.115*** (4.17)
Continuous R&D = 1	0.229*** (10.27)	0.201*** (6.08)
Patent = 1	0.107*** (5.43)	0.132*** (2.64)
Founder qualification[a]		
Founder apprenticeship	0.019 (0.50)	−0.150* (−1.82)
Founder vocational college	0.057 (1.31)	−0.090 (−0.97)
Founder College/University	0.052 (1.17)	−0.033 (−0.35)
Founder industry experience = 1	0.001 (1.46)	0.001 (0.73)
Founder previous enterprise = 1	0.007 (0.52)	0.025 (0.84)
Startup has employees = 1	0.003 (0.24)	0.013 (0.43)
Economics/Business = 1	0.059*** (2.66)	0.017 (0.30)
Natural science = 1	0.031 (1.17)	0.023 (0.35)
Engineering science = 1	−0.021 (−0.98)	−0.080 (−1.53)
Mathematics/Computer Science = 1	−0.039 (−1.03)	−0.047 (−0.54)
Humanities = 1	0.013 (0.48)	0.001 (0.02)
Cutting-edge technology manufacturing	0.010 (0.33)	0.302*** (3.23)
High-technology manufacturing	−0.009 (−0.37)	0.218** (2.39)
Technology-intensive services	−0.015 (−0.76)	0.223*** (2.64)
Software	−0.004 (−0.14)	0.375*** (4.02)
Skill-intensive services	−0.010 (−0.46)	0.125 (1.39)
Business-oriented services	0.023 (0.80)	0.065 (0.48)
Public support		
Subsidized bank loan	−0.067** (−2.29)	−0.053 (−0.67)
Grant/Subsidy	−0.017 (−1.05)	0.031 (0.91)
State guarantees	−0.014 (−0.41)	0.086 (1.14)
Public venture capital	0.101 (1.27)	– –
Other support	0.038 (1.39)	0.071 (1.57)
Year = 2012	0.030* (1.88)	0.069* (1.65)
Year = 2013	0.040** (2.05)	0.043 (0.89)
Year = 2014	0.023 (1.08)	0.042 (0.75)
Foundation year = 2010	0.040* (1.87)	0.057 (1.02)
Foundation year = 2011	0.068*** (3.60)	0.035 (0.70)
N	2,568	863

Note. *t* statistics in parentheses, * $p < .10$, ** $p < 0.05$, *** $p < .01$. Dummy variable DNovel indicates that the startup has introduced a market novelty. Dummy variable DInno indicates that the startups has innovative product(s) that are not based on tested and commonly used technology. Other notes see previous Table. [(a)] ref cat: no formal degree.

Abbreviation: prob, probability.

[a]Ref cat: no formal degree.

TABLE A9 Marginal effects of multinomial logit regression results for variable Inno, matched cohorts Cleantech and non-Cleantech startups, outcomes years 2011–2014

	Categorical variable Inno, marginal effect dy/dx Applying common technology	New combination of existing technology	Application of third party new technology	Self- developed new technology
Cleantech	−0.112*** (−4.17)	0.078** (2.56)	0.042* (1.81)	−0.008 (−0.34)
Continuous R&D = 1	−0.193*** (−5.90)	0.0315 (0.87)	−0.044 (−1.62)	0.206*** (6.44)
Patent = 1	−0.126** (−2.31)	0.023 (0.49)	−0.021 (−0.51)	0.125*** (3.90)
Founder qualification[(a)]				
Founder apprenticeship	0.159* (1.91)	0.036 (0.42)	−0.100 (−1.29)	−0.095 (−0.99)
Founder vocational college	0.086 (0.92)	0.059 (0.62)	−0.048 (−0.51)	−0.098 (−0.96)
Founder College/University	0.040 (0.43)	0.135 (1.37)	−0.086 (−0.92)	−0.089 (−0.86)
Founder industry experience = 1	−0.001 (−0.84)	−0.001 (−0.89)	0.001 (0.76)	0.001 (1.32)
Founder previous enterprise = 1	−0.027 (−0.92)	−0.042 (−1.31)	0.012 (0.52)	0.057** (2.09)
Startup has employees = 1	−0.011 (−0.40)	−0.008 (−0.24)	−0.001 (−0.04)	0.020 (0.70)
Economics/Business = 1	−0.001 (−0.02)	−0.006 (−0.11)	−0.003 (−0.07)	0.009 (0.24)
Natural Sciences = 1	−0.006 (−0.09)	−0.092 (−1.45)	−0.036 (−0.62)	0.135*** (3.11)
Engineering Science = 1	0.096* (1.78)	−0.028 (−0.55)	−0.107** (−2.37)	0.039 (1.00)
Mathematics/Computer Science = 1	0.063 (0.69)	−0.043 (−0.50)	−0.078 (−0.98)	0.058 (0.93)
Humanities = 1	0.010 (0.14)	−0.076 (−1.07)	−0.008 (−0.15)	0.074 (1.40)
Cutting-edge technology manufacturing	−0.354*** (−3.54)	0.208** (2.36)	−0.033 (−0.41)	0.179** (1.96)
High-technology manufacturing	−0.278*** (−2.85)	0.149* (1.86)	−0.102 (−1.37)	0.231*** (2.69)
Technology-intensive services	−0.287*** (−3.17)	0.231*** (3.10)	−0.054 (−0.78)	0.111 (1.36)
Software	−0.458*** (−4.67)	0.390*** (4.28)	−0.056 (−0.70)	0.125 (1.42)
Skill-intensive services	−0.189** (−1.98)	0.147* (1.83)	−0.122* (−1.72)	0.164* (1.87)
Business-oriented services	−0.136 (−0.98)	0.128 (0.94)	−0.128 (−1.38)	0.136 (0.94)
Access to finance				
Subsidized bank loan	0.050 (0.63)	−0.083 (−0.99)	0.117 (1.46)	−0.083 (−1.22)
Grant/Subsidy	−0.030 (−0.90)	0.015 (0.38)	0.061** (2.06)	−0.045 (−1.43)
State guarantees	−0.087 (−1.15)	−0.044 (−0.53)	0.151* (1.83)	−0.019 (−0.29)
Public VC	−0.316*** (−16.19)	0.023 (0.17)	0.159 (1.14)	0.133 (1.07)
Other support	−0.070 (−1.56)	−0.079 (−1.53)	0.072* (1.69)	0.077 (1.54)
Year = 2012	−0.074* (−1.76)	0.063 (1.41)	0.024 (0.64)	−0.014 (−0.40)
Year = 2013	−0.028 (−0.59)	0.153*** (2.83)	−0.158*** (−10.56)	0.033 (0.78)
Year = 2014	−0.054 (−0.97)	0.048 (0.83)	0.035 (0.68)	−0.029 (−0.67)
Foundation year = 2010	−0.062 (−1.14)	0.060 (1.01)	0.018 (0.42)	−0.016 (−0.33)
Foundation year = 2011	−0.034 (−0.71)	0.003 (0.07)	0.012 (0.31)	0.018 (0.41)
N	875	875	875	875

Note. see previous Table.

[a]Ref cat: no degree.

TABLE A10 Marginal effects of multinomial logit regression results for variable Novel, matched cohorts Cleantech and non-Cleantech startups, outcomes years 2011–2014

	Categorical variable Novel, marginal effect dy/dx No market novelty	Novelty regional market	Novelty national market	Novelty world market
Cleantech	−0.021 (−1.60)	0.024*** (3.07)	0.002 (0.26)	−0.005 (−0.58)
Continuous R&D = 1	−0.231*** (−10.14)	0.048*** (3.28)	0.064*** (4.49)	0.118*** (7.72)
Patent = 1	−0.078*** (−3.64)	−0.014 (−0.90)	0.041*** (3.50)	0.051*** (5.07)
Founder qualification[(a)]				
Founder apprenticeship	−0.0131 (−0.33)	0.012 (0.56)	−0.000 (−0.01)	0.000 (0.02)
Founder vocational college	−0.060 (−1.35)	−0.002 (−0.10)	0.029 (1.00)	0.033 (1.13)
Founder College /University	−0.046 (−1.03)	−0.012 (−0.49)	0.038 (1.27)	0.020 (0.69)
Economics/Business	−0.050** (−2.14)	0.004 (0.25)	0.018 (1.36)	0.027** (2.25)
Natural Sciences	−0.034 (−1.24)	0.021 (1.22)	−0.012 (−0.69)	0.025* (1.73)
Engineering	0.019 (0.89)	−0.006 (−0.45)	−0.001 (−0.13)	−0.0111 (−0.91)
Math/Computer Science	0.0545 (1.26)	−0.027 (−0.84)	−0.004 (−0.18)	−0.022 (−0.99)
Humanities	−0.023 (−0.87)	0.020 (1.25)	−0.004 (−0.28)	0.007 (0.48)
Founder industry experience = 1	−0.001* (−1.82)	0.000 (1.19)	0.001 (1.58)	0.000 (0.12)
Founder previous enterprise = 1	−0.0041 (−0.33)	−0.008 (−1.13)	0.023** (2.35)	−0.009 (−1.07)
Startup has employees = 1	−0.005 (−0.40)	−0.006 (−0.94)	0.008 (0.81)	0.004 (0.41)
Cutting-edge technology manufacturing	−0.010 (−0.31)	0.000 (0.02)	−0.021 (−0.99)	0.031 (1.43)
High-technology manufacturing	0.009 (0.39)	−0.013 (−1.07)	−0.022 (−1.21)	0.025 (1.50)
Technology-intensive services	0.013 (0.61)	−0.001 (−0.08)	−0.015 (−0.92)	0.003 (0.22)
Software	0.010 (0.38)	−0.011 (−0.79)	−0.0133 (−0.62)	0.013 (0.77)
Skill-intensive services	0.002 (0.11)	0.000 (0.06)	−0.023 (−1.37)	0.020 (1.22)
Business-oriented services	−0.027 (−0.87)	0.004 (0.29)	0.012 (0.46)	0.011 (0.49)
Public support				
Subsidized bank loan	0.074** (2.50)	−0.015 (−1.10)	−0.017 (−0.76)	−0.041** (−2.47)
Grant/Subsidy	0.024 (1.42)	−0.004 (−0.53)	−0.009 (−0.84)	−0.009 (−0.83)
State guarantees	0.015 (0.45)	−0.025** (−2.34)	0.004 (0.17)	0.005 (0.25)
Public VC	−0.063 (−1.00)	−0.035*** (−7.10)	0.037 (0.76)	0.061 (1.36)
Other support	−0.038 (−1.40)	0.005 (0.38)	0.010 (0.50)	0.023 (1.18)
Year = 2012	−0.035** (−2.15)	−0.011 (−1.30)	0.00226 (0.20)	0.044*** (4.01)
Year = 2013	−0.039** (−2.04)	−0.004 (−0.41)	0.018 (1.34)	0.025** (2.17)
Year = 2014	−0.024 (−1.17)	−0.020** (−2.05)	0.005 (0.40)	0.039*** (2.67)
Foundation year = 2010	−0.040* (−1.90)	0.009 (0.98)	0.020 (1.30)	0.010 (0.79)
Foundation year = 2011	−0.073*** (−3.89)	0.025*** (2.90)	0.015 (1.15)	0.032*** (2.69)
N	2,551	2,551	2,551	2,551

Note. see previous Table.

[a]Ref cat: no formal degree.