CHAPTER 7

GREEN START-UPS

Hanna Hottenrott, Technical University of Munich (TUM)
and Leibniz Centre for European Economic Research (ZEW)

Abstract

New companies that lower the environmental damage associated with producing and consuming goods and services or that directly contribute to higher sustainability standards are crucial in the transition to a more environmentally-friendly economy. Green start-ups are, however, confronted with multiple challenges including the triple externality problem. By investing in greener solutions and by adopting more sustainable business practices, founders carry much of the costs and risks associated with the entrepreneurial activity. The social returns to their efforts, however, likely exceed the benefits that founders earn. This is also reflected in the findings on who founds green start-ups, where they locate, how they perform and how they are financed. This review presents key insights from the still small - but growing - stream of research on green start-ups. Given the characteristics of founders and their green start-ups, it also discusses implications for the public support of green start-ups and policy more generally.

1. Introduction

Given the increasing visibility of the consequences of climate change, governments have declared climate emergencies and society increasingly demands more decisive action toward environmental protection. The transition to a low-carbon economy and a more sustainable approach to economic activity has emerged as the primary solution to address the global environmental crisis. Hence more than 140 countries, encompassing approximately 90% of global CO2 emissions, have already taken the step of announcing or contemplating net zero emissions targets by the year 2050. However, the attainment of these ambitious climate goals cannot be accomplished solely by scaling up existing technologies, such as renewable energy or current material recycling methods. Moreover, environmental disaster goes beyond climate change and includes pollution of the oceans and drinking water, as well as various pollutants in the air and soil. The real game-changer therefore lies in innovation: the generation and diffusion of ground-breaking ideas, products, processes and methodologies beyond individual sectors or applications. Thus, a crucial aspect of the green transition involves individuals and organisations embracing environmentally friendly practices, and pursuing radical and continuous innovation to develop sustainable solutions (Criscuolo and Menon, 2015).

Recent numbers show that companies affected by climate change are indeed more likely to introduce eco-innovations (Horbach and Rammer, 2022). This indicates that societal demand and policy initiatives are providing incentives for companies to react and innovate in environmentally relevant areas. While attention until very recently has been devoted almost exclusively to understanding the motivations, incentives and environmental efforts of established organisations (Brunnermeier and Cohen, 2003; Hottenrott and Rexhäuser, 2015; Aghion et al., 2016; Hottenrott et al., 2016; Horbach and Rammer, 2020), the spotlight is now turning to start-ups (Demierel et al., 2019; Kuckertz et al., 2019; Goldstein et al., 2020; Chapman and Hottenrott, 2022).

Green start-ups have the potential to play a crucial role in facilitating the transition to a low-carbon future. Identifying green start-ups is, however, a challenge as well as a matter of definition. In general, green start-ups can be defined as newly established companies that offer products or services with environmental benefits. While this definition is already quite comprehensive, it does not sufficiently incorporate business practices and processes within the companies that are more sustainable than current standards (Trapp and Kanbach, 2021). Thus, expanding the definition of what makes a start-up green to include all new companies that significantly reduce the negative impact of any business activity on the climate and the environment more generally seems plausible (Saari and Joensuu-Salo, 2020; Chapman and Hottenrott, 2022). Some studies propose a more narrow definition related to emission reduction or certain 'clean tech' applications (see e.g. Bjornali and Ellingsen, 2014; Leendertse et al., 2020; Goldstein et al., 2020). Since environmentally friendly products and process innovations also typically impact emissions directly and indirectly, the broader definition aligns well with the narrower one, even though some of the environmental benefits may not be directly related to emissions. When trying to detect and study green companies, the empirical literature has mainly relied on measuring green innovation using either survey data (such as from the Community Innovation Surveys) or information from patents. In the latter case, businesses that file patent applications that are classified as green, according

to international classification schemes (such as the WIPO Green Inventory, the OECD EnvTech and the ECLA Y02 class) are regarded as green while others are 'grey' or even 'brown'. One challenge with this approach in the case of start-ups is that they are typically not part of the sampling population of larger-scale surveys, such as the CIS; also, nascent companies typically do not yet hold patent portfolios that are comprehensive enough for a detailed analysis, they have not yet filed patent applications or they do not patent at all. Especially in the case of fledgling companies in some service-oriented or digital sectors, an analysis of patenting may be less meaningful than in high-tech sectors for measuring the green orientation of companies. Using text-based indicators derived from companies' websites may provide a useful additional indicator for the detection of young, green businesses.

For a better assessment of the role of green start-ups in the transformation to a more sustainable economy, it is crucial to understand how and where they emerge, how they develop and how their impact can be evaluated. Understanding these factors will enable the design of ecosystems and policy frameworks that are conducive to the birth and development of young green companies.

The goal of this chapter is, therefore, to provide a focused overview of research on green start-ups with regard to three main questions:

- What makes start-ups green and what are the central challenges they face?
- Who creates green start-ups and how do they perform?
- How can innovation and entrepreneurship policy support green start-ups?

Relevant articles for this review were collected until January 2024 and include peer-reviewed journal articles, discussion papers and policy reports. Articles have been screened for quality and compatibility before being included in the overview with a focus on more recent studies. The review, therefore, does not claim completeness or geographic coverage. The term 'start-up' used here implies that founders pursue the goal to grow the business in terms of sales and employees if possible. This definition is applied to new independent ventures as well as corporate spin-offs. However, the focus of this essay is clearly on the former. Some of the entrepreneurs may have substantial experience from their previous business formation activity or their previous employment. The terms entrepreneur and founder are used interchangeably.

2. The role of green start-ups in the green transition

Young green companies likely play an essential role as they develop and introduce new products and services or implement more sustainable ways of offering existing ones. Similar to innovation in general, new green, innovative companies benefit from a lower path dependency compared to established businesses. This allows them to adopt more radical approaches without facing the dilemma of giving up profits in 'dirtier' products and services (Bendig et al., 2022). Moreover, in young organisations, the resistance to change within the company tends to be significantly lower, allowing decision-makers to pursue more radical approaches (Harris and Ogbonna, 1998; Young, 2000).

Besides their direct role in green innovation, green start-ups can promote the adoption of environmental technologies by established companies with less sustainable business models by providing a 'proof of concept' and by creating pressure to innovate (Hall et al., 2010; Cojoianu et al., 2021; Bendig et al., 2022). If successful, they may also set new environmental standards, which are subsequently demanded by customers. These factors contribute to the special role that new companies play in the development and diffusion of green innovations, and explain the high expectations of policymakers and environmentalists.

Yet, despite the recent increase in the emergence of green start-ups (Fichter et al., 2023), it is still only a small fraction of new businesses that can be classified as green (Goldstein et al., 2020; Chapman and Hottenrott, 2022), pointing to some factors that hold entrepreneurs back from starting new companies offering greener products or pursuing more environmentally friendly business models.

From what we know based on economic research, there are at least two important factors that may hold back the rise of a new green business wave. The first relates to the double externality problem (Popp et al., 2009) that has long been discussed in the context of green innovation and which may apply, especially to young companies: being confronted with externalities related to environmental research and development (R&D), i.e. not all the returns of such R&D will be appropriated by the investing company, implying that the private return on investment is likely to be smaller than the societal one (Hottenrott and Rexhäuser, 2015). Thus, there is a positive externality from the innovation the environmental innovation to society. At the same time, green start-ups generate positive externalities related to the reduced adverse environmental impact, which the founders or owners are typically not compensated for via the prices of their products and services. Greater greenness at the expense of higher costs of production or service provision through abatement and careful resource use may result in benefits for the end-user and the environment. Yet it is not self-evident that the benefiters have a higher willingness to pay. Besides these challenges that relate to the 'green side', founders are also likely to face the typical problems related to the liability of newness that results in financing challenges and the need to build a brand and reputation, as well as the challenges of building a functioning organisation (Stinchcombe, 1965). This constitutes a second externality. Importantly, in the case of green start-ups there exists a third positive externality. It results from the pressure to innovate that their activities have on established companies. This way start-ups contribute to the overall creation of innovation in the economy as well as the diffu-

sion of green technologies beyond their own organisation. Yet this diffusion may also result in larger corporations adopting green innovations fast(er) and with economies of scale and scope, hence overtaking the green start-ups' products and services. Hence, in the context of green start-ups, it is a 'triple externality problem' that affects incentives of founders. Anticipating such developments, it lowers entrepreneurs' incentives to invest time, money and effort in the formation of green start-ups as much of the returns to their efforts will be entrepreneurs will be appropriated by others. It may also lower the willingness of investors to invest in the scaling of such ventures.

Thus, while on the one hand we can expect that new companies have a comparative advantage in developing novel and greener approaches as they are less path-dependent and less entrenched in existing solutions, they are also confronted with financing constraints, a limited track record in supplier and customer relationships, and business model uncertainty (Hottenrott et al., 2018). Moreover, market and regulatory uncertainty also play important roles in the incentives to found green start-ups – as well as from an investor's perspective to invest in one. Finally, while competition may drive green innovation in a race for the conscious consumers, it may also imply market exits for younger companies that fail to successfully compete against companies that, because of their size and market reach, leverage the innovation or technology more efficiently.

Despite these challenges, we do see an increasing number of green start-ups in Europe (Fichter et al., 2023) as well as rising investment volumes in green technology (Inderst et al., 2012; Fichter et al., 2023). In addition, a larger share of (new) jobs can be classified as green (Janser, 2018). Cohen and Winn (2007) indeed argue that the more pressing environmental concerns will be, the larger the opportunities for entrepreneurs to earn returns, while at the same time serving the green purpose. They argue that there is not necessarily a trade-off between private profitability of a business and its environmental orientation or benefit. Instead, new opportunities arise from the challenge to overcome existing solutions. As existing practices may become obsolete or increasingly irresponsible, entrepreneurs may spot these opportunities and replace harmful practices with more sustainable ones and thereby reap the benefits.

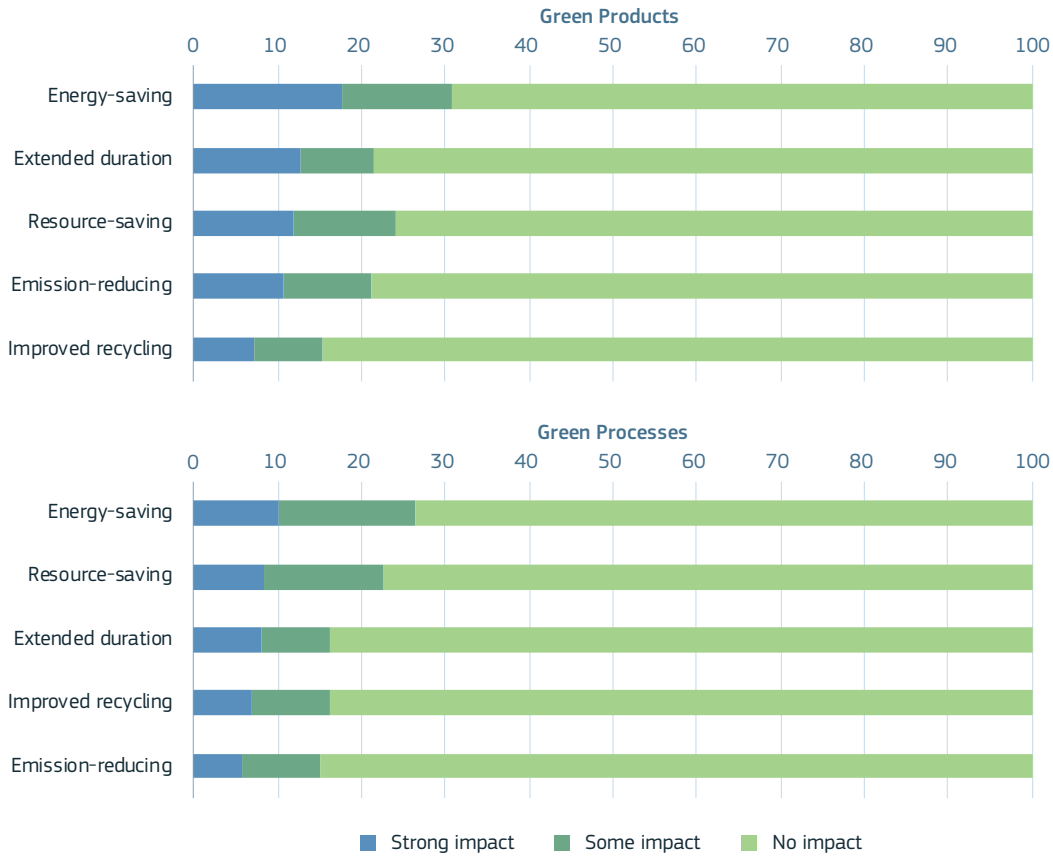
This shows that understanding the factors that drive green start-up formations is crucial due to the potential societal benefits they create. However, the intrinsic motivations of founders and the external drivers that facilitate green start-ups seem complex, and the factors that play a role are likely different from other entrepreneurial ventures. In addition, identifying the benefits of start-ups' green engagement (Ambec and Lanoie, 2008) that go beyond the immediate effects on the environment, i.e. in terms of classical business performance, is relevant for understanding the persistence of the rise in green start-ups and their sustainability in the longer term. Exploring potential hampering factors in the birth and development, as well as strategies that support green start-ups in overcoming barriers, appears, moreover, crucial for the design of environmental policies (Cojoianu et al., 2021) and start-up support programmes (Hottenrott and Richstein, 2020; Zhao and Ziedonis, 2020).

3. What makes start-ups green and who founds them?

New companies can be characterised as green-based on multiple dimensions. One way to categorise greenness is to differentiate between 1) products and their environmental impact when consumers use them, and 2) green processes and business practices that the start-ups engage in. For both the measurement is relative to current standards of sustainability and how high the environmental impact of the product or process is on either the consumer's or the company's side.

Data from more than 5 000 start-ups founded between 2011 and 2017 in Germany were analysed in Chapman and Hottenrott (2022) along these two dimensions. The information had been collected as part of the IAB-ZEW Start-up Panel, which was based on structured, computer-aided telephone interviews. The responses to a set of questions related to the greenness of their businesses shows that there is considerable variation between a) the extent to which start-ups provide green products or b) engage in green business activities. Figure 1 summarises the responses to the 10 survey items along the dimension of greenness and whether they are related to products (left) or internal processes (right). The most frequently reported dimension of greenness is related to energy-saving properties, both on the side of consumers and within the company. Other resource-saving properties are also relatively common. However, within a company's own processes they play a larger role than reducing emissions, improving recycling or extending the duration of process innovations. When looking at start-up products, on the other hand, the resource-saving properties of new products seem relatively more important than improved recycling.

Figure 7-1 Share of start-ups reporting strong or some environmental impact from their products on the side of consumers (up) and from internal process innovations (down)



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Source: see Chapman and Hottenrott (2022) for details on the survey and question design.

The figure above shows the share of businesses that report a strong impact in darker green, report some impact in lighter green, and show no impact in grey.

'Going green' in the context of established organisations has typically been explained by the cost-saving potential of resource-saving innovations (Rammer and Rexhäuser 2014), customer expectations or being driven by regulation (Hottenrott and Rexhäuser, 2015; Ambec and Lanoie, 2008; Porter and van der Linde, 1995). This is a pattern that can also be observed in the context of start-ups. The important role of consumers is reflected in the relative importance of products that are energy-saving, have a longer product life expectancy, or contribute to the saving of some resources other than energy. In line with the Porter hypothesis, which predicts that companies have incentives to go green if it is economically attractive, the data also shows that energy and resource-saving green-process innovations within the businesses is more frequent than those green activities for which the private returns are less clear (Ambec et al., 2013). The right-hand side of Figure 1 illustrates this with those green processes that likely have higher social than private returns as they are less frequent, i.e. those that reduce emissions or improve recycling. This pattern illustrates the private versus social returns to green innovation: where private returns are higher, the triple externality problem is less pressing and such activities are hence much more frequent. Overall, the survey, which reflects a representative sample of new businesses in Germany, illustrates that in all categories the share of businesses reporting green attributes hardly exceeds 30%, implying that green start-ups are the minority of new businesses and the vast majority are not green in any of these dimensions.

The question is, therefore, what characterises those founders who create green businesses? It is generally assumed that the objective decision-making processes of their founders drive the environmental engagement of companies, including start-ups. This approach involves founders objectively evaluating the value and obstacles associated with environmental engagement and making a decision based on this assessment. However, starting a new company involves a substantial amount of risk, especially when it is active in business segments that are not long established, and the more fundamental or radical the greener solution is compared to existing products and services. In these cases the uncertainty in terms of costs, consumer expectations and sales, as well as technology development and regulation, may be high. As outlined before, creating a green company may come with additional challenges (Pacheco et al., 2010), resulting in reduced incentives to start a business or severe hurdles for business expansion and hence environmental impact.

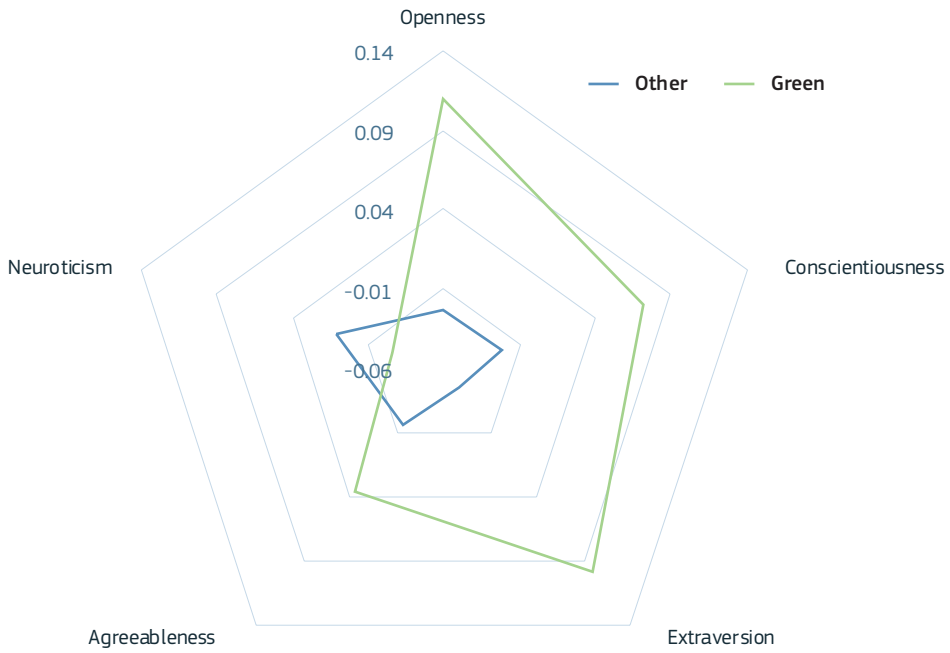
In new organisations, however, the business model itself may centre on environmental concerns, thereby addressing stakeholder expectation up front. These firms are 'born green' rather than 'turned green' (Demirel et al., 2019). Born-green start-ups are therefore likely to be different from previous generations of new innovative companies, with environmental goals driving their product design, operations and the market they serve (Criscuolo and Menon, 2015; Esty and Winston, 2009).

This implies that the emergence of a green start-up may be initially driven by its environmental motivation – either in terms of products or in terms of business processes and the design of its operations. Thus, the detection of a business opportunity that is greener than the established means of production, service provision or existing products may be central to the emergence of green start-ups. It seems likely, therefore, that green start-ups are founded based on different core values, which may impact market positioning and success as measured by conventional indicators. Moreover, in some markets, green start-ups co-exist and compete against established companies, thus stressing the role of consumer preferences and the degree of green innovation between established and younger companies.

When investigating founder characteristics, including both cognitive skills and personality traits appears plausible. Research in the fields of psychology and entrepreneurial personality indeed stresses the significant role that founder personality plays in predisposing them and their start-ups towards environmental engagement (Hirsh, 2010; Milfont and Sibley, 2012; Busic-Sontic et al., 2017). Specific combinations of personality traits can incline founders towards favouring the integration of green products and innovations in their start-ups, while other traits may lead to a less favourable disposition. One way of capturing an individual's baseline personality is looking at the well-established concept of the 'Big 5' personality traits: openness to experience, conscientiousness, extraversion, agreeableness and neuroticism (Brandstätter, 2011; Kerr et al., 2018). Thus, certain traits, such as openness to experience, conscientiousness and extraversion, may increase the likelihood that someone founds a green start-up due to differences in how these traits affect a person's perception of opportunities and threats related to the green opportunity. Scoring higher on these traits may also predispose someone to detect a green business opportunity (Chapman and Hottenrott, 2022).

In a study that analyses data for more than 5 000 independent, new businesses founded between 2011 and 2017, Chapman and Hottenrott (2022) show stark differences in these personality traits between founders of green versus other businesses while accounting for various other founder and firm characteristics. Figure 2 shows that all traits – except neuroticism – are much more pronounced in founders that started a business that is green in any of the dimensions discussed above (i.e. these firms perform above the sample mean for all items).

Figure 7-2 Personality traits of green start-up founders



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Source: Predicted item scores from Chapman and Hottenrott (2022)

The striking differences in founder personality traits show that the decision to engage in environmental business activities is not solely driven by objective factors such as expected financial returns, but is also influenced by inherent founder characteristics. Consequently, even in cases where the benefits are recognised and barriers are minimised, founders with certain combinations of traits may still not steer their start-ups towards embracing greener products and innovations. On the other hand, it suggests that barriers to green activities may be perceived as differently binding depending on the individual founder characteristics. Personality traits may therefore contribute to how severe an entrepreneur perceives certain hurdles and constraints. The uncertainty may therefore be more or less discouraging, depending on the relevance that a person devotes to the factors that define the degree of uncertainty. Thus, the risks and returns to green business activity may be partially subjective, so we can conclude that within the same regulatory and business environment some people may pursue green business opportunities while others do not. While there are certainly some factors that can be assessed objectively, others may require a substantial amount of the founder's own judgement and taste. In the domain of green technology, such subjective assessment can be explained by several factors, such as the uncertainty and complexity of underlying technologies, the ambiguity in the assessment criteria depending on the time horizon and the lack of established evaluation frameworks for new technologies, and uncertainty in market demand and regulatory environment (Demirel and Parris, 2015; Petkova et al., 2014).

In summary, these insights suggest that founder personality traits are an important factor – outside the control of regulation and innovation policy – as those possessing different (combinations of) personality traits may respond differently to incentives, barriers or benefits, and thus different policy interventions or incentives may be needed across personality types. While in young, small businesses the influence of the founders is typically undisputed, it remains unclear whether these insights persist as start-ups develop and become more mature organisations. Some research, however, indicates that, including in established companies, the founder's impact is sustained through their effect on corporate culture, which is also a determinant of eco-innovation (Kiefer et al., 2019).

Besides baseline personality there are likely further motives that play a role. Research has long shown that preferences and experiences shape economic behaviour (Horbach and Jacob, 2018). Altruistic motives may also play a role in shaping a founder's mission to develop a business that positively or less negatively impacts the environment. This aspect further illustrated the soft boundaries between green entrepreneurship and social entrepreneurship (Saari and Joensuu-Salo, 2020; Neumann, 2022; Hörisch et al., 2017). Benefits for the environment or the reduction of adverse impacts could also be considered a social impact if they reduce harm in vulnerable regions or groups of people, plants or animals.

Moreover, it may not only be the personality of the founders that matters. Wealthier individuals may feel the desire to give something back to society and hence start companies where the profit motivation is secondary compared to the social mission. In other cases, it may be the founders who have the green idea and seek socially and environmentally oriented investors to support their business financially. Again, the mission to serve the environment with the business may be at least as important as the profitability of the company in such cases (Alt et al., 2023).

In some instances, however, green activities may be pursued for marketing and branding reasons rather than for the green purpose as such. While independent of the motive, the outcome of these activities is still green, showing that it's not only internal factors such as personality or preferences that play a role, but also outside factors such as market demands and norms that affect entrepreneurial incentives. Reacting to changing consumer needs and expectations can be a rational and profitable strategy, resulting in green start-ups that are not necessarily mission-driven or inspired by the founders' entrepreneurial preferences.

In this context it seems important to differentiate branding and 'green washing' from those entrepreneurial activities that have an actual positive environmental impact. Green washing would be considered in cases where the products are labelled as 'green' while, in fact, there is no such benefit for either the consumer or the business operation. In reaction to changing consumer demands, most companies have started to use eco-labels or marketing tools that stress the 'green' aspects of their products, even though the overall ecological footprint may not have changed over time. For start-ups without a product or service history, this comparison is harder to make. One extreme example of green washing in the domain of product packaging applied by several producers, including start-ups, was the introduction of bottles that appeared to be made from recycled paper. However, the paper packaging was only the outside shell of a conventional plastic bottle. The statement that the outside packaging was made from 100% (recycled) paper was clearly misleading and consumer attention led to relatively quick detection.

Such attempts of green washing or even simply exaggerating the environmental benefits may therefore not be an ideal strategy to establish a new product or service. Ioannou et al. (2023) estimate that established companies that are perceived to be green washing experience a significant drop in their customer satisfaction scores. The impact of green washing on the performance of green start-ups is less well understood. It seems likely, however, that in a phase of trust and reputation-building, customers will punish green washing even harder, which can lead to a quick demise of the new business.

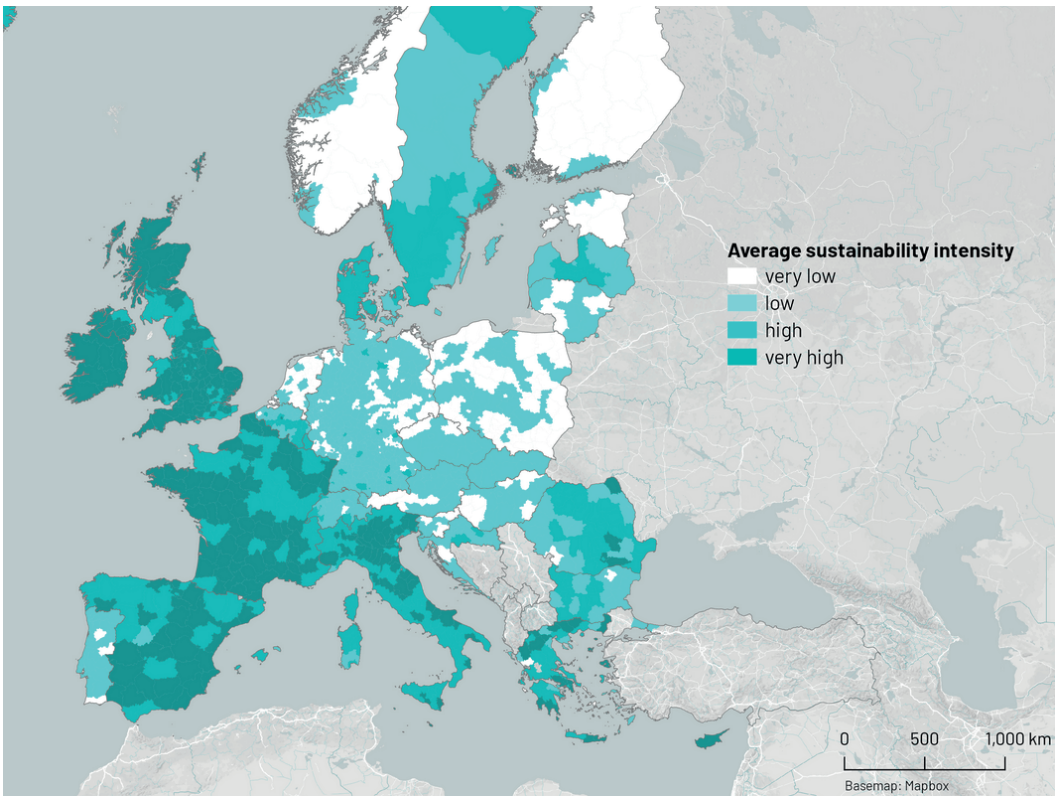
4. The geography of sustainable businesses

In some cases, laws and regulations can be considered strong external drivers of eco-innovations and more sustainable business practices (Hottenrott and Rexhäuser, 2015; Meng et al., 2020; Horbach and Rammer, 2020). In certain technology fields, by requiring thresholds for energy-use, recyclability or durability, entrepreneurs may be steered towards finding solutions for new products and services that fulfil the requirements. In the case of older, established companies, we know that regulation can indeed be an effective way of reducing negative environmental impacts directly (Aghion et al., 2016; Calel and Dechezleprêtre, 2016). For new companies, the evidence is less clear-cut. The results presented above suggest that consumer demand, climate change affectedness, and founders' own preferences play strong roles. In some areas such as energy or consumer products, regulation can indeed shift the relative attractiveness of investments substantially. In other areas, regulation – or more precisely regulatory uncertainty – could also render entrepreneurial action even more risky and increase the uncertainty about any return on investment, such that founders rather refrain from devoting money and other resources to such start-ups.

The regulatory environment typically depends on the location of a company and – hence – variation in green innovation can be a flection of differences in laws and regulation and set or reduce incentives. When looking at the geography of sustainable companies, we also see a strong regional variation in sustainability intensity, even across European regions. Figure 3 shows the average regional sustainability intensity as measured by the occurrence of terms related to green business practices on company websites relative to the entire website texts. Using website texts instead of patents for identifying green companies has its ups and downs. The main advantage is that it allows capturing green activities that are not inventions in the sense of intellectual property rights. As discussed before, most green activities may stem from improving existing products by making them more environmentally friendly or by providing greener solutions to established business practices. In some technology-based sectors, there can be a significant overlap between firms that are green in this sense and those that hold patents that can be classified as green (Goldstein et al., 2020). In other cases, however, such as in service or digital sectors, green activities can be essentially non-patentable (Kinne et al., 2024). Thus looking at websites enables capturing green companies even if they do not patent in green technologies, e.g. solar panel installation companies, or those that buy rather than make the green technology for the provision of a sustainable product or service, e.g. packaging companies that license the technology from the inventor. Comparing Figure 3, which is based on website-measured sustainability, to a map as presented in Figure 4, which reflects green patents, shows similarities as well as differences in the geographic scope of green activities. Website-based green activities are relatively stronger in Belgium, Ireland, Spain and regions in the southeast of Europe, areas that would have been under-measured in their relative importance using patents. Yet the map shows that regions with a high green patenting intensity also show a high sustainability score in the web-based data and vice versa, especially in Germany, Poland, the Netherlands and other regions in central Europe with high patenting intensity, where the average sustainability intensity is lower than what we would have expected based on patents. However, it needs to be acknowledged that the two measures are difficult to compare directly. The different geographic patterns, however, show that some of sustainable business activity is not captured using patents as an indicator of green innovation.

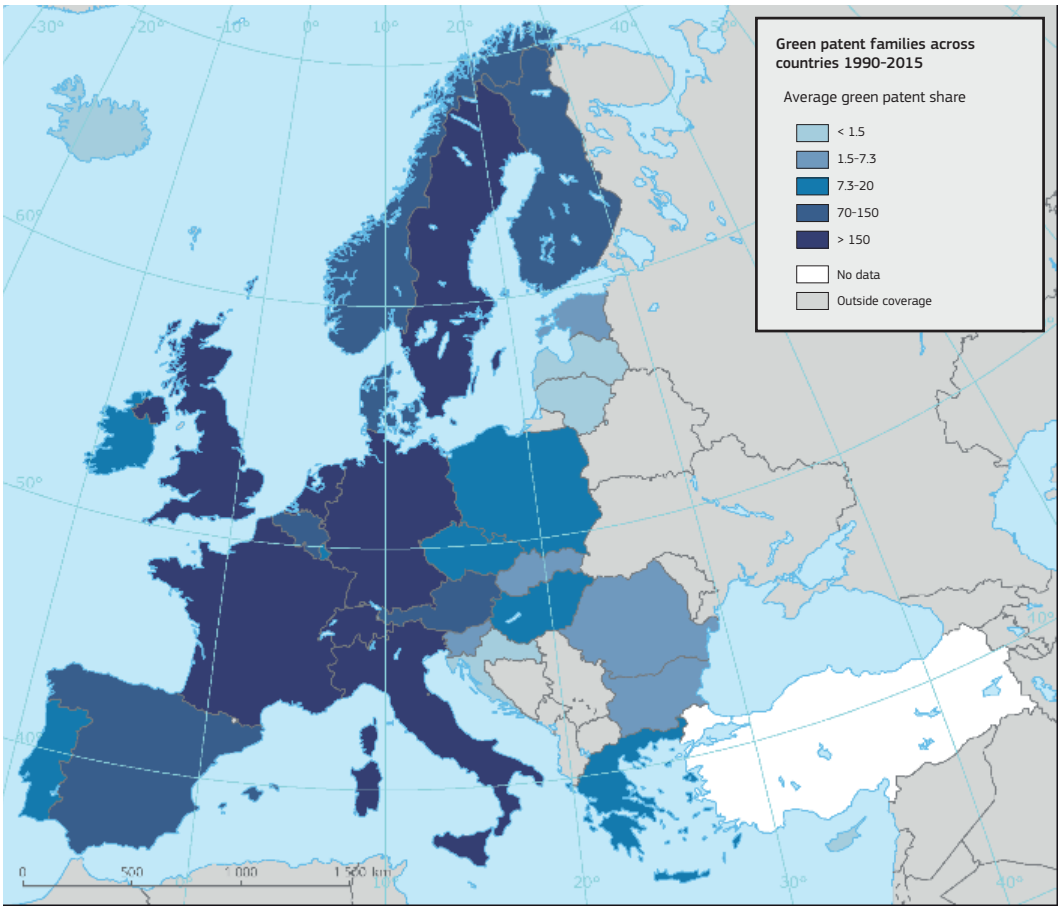
Moreover, a more fine-grained geographical analysis reveals substantial heterogeneity within regions. For example, Italy scores high to very high in both measures: the map presented in Figure 5 (at left) shows that much of the green activity in the Turin area happens outside of the city centre. To the contrary, in the area of Frankfurt and neighbouring counties (Figure 5, at right), we see a hotspot of high sustainability intensities in the downtown area, as well some districts further outside that show a high relative intensity.

Figure 7-3 **Companies' sustainability scores across Europe**



Source: Istari.ai, September 2023.
Note: measured based on company websites

Figure 7-4 Green patent families across Europe (1990-2015 averages)



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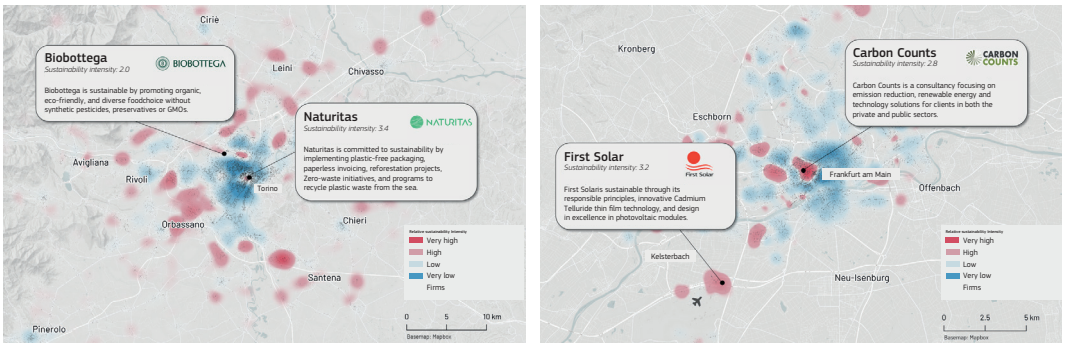
Source: European Environment Agency.
Note: measured based on company websites

Figure 7-5 Local sustainability scores of companies in the area of Turin, Italy (left) and Frankfurt, Germany (right)



Source: Istari.ai, September 2023.
Note: Measured based on company websites

The literature on environmentally friendly innovations provides useful insights on the role of local knowledge spillovers for the emergence of green businesses – or rather the introduction of green practices in the business sector more generally (Florida, 1996; Oltra and Saint-Jean, 2005; Rennings and Rammer, 2009; Zeppini and van den Bergh, 2011). Most recently, Horbach (2023) shows that the higher the existing stock of environmentally related patents in a region, the higher the probability that a start-up introduces eco-innovations. In line with this finding, Colombelli et al., (2021) illustrate that the birthplaces of green start-ups in Italy show higher levels of knowledge variety in terms of green and 'dirty' technology, which points to the relevance of diverse and heterogeneous knowledge sources for the development of green innovations. Thus, pure 'green clusters' may not be what we would expect based on these insights. Similarly, Kim et al. (2023) show that green-tech absorptive capacity and green-tech innovative capacity in a region both correlate with a higher number of new green-tech enterprises. The co-location of green hotspots and agglomerations of low-sustainable businesses in the two example regions as illustrated above underscore this argument. Research on the locations of blockchain companies in the US shows that blockchain-based companies are more likely to have sustainable applications if there are located on a local eco-system that allows them to have close ties with other sustainable companies (Kinne et al., 2024). This result indicates that green ideas may spill over from non-green to green companies, but also the other way around. If that was the case more generally, the impact of green start-ups may be even more important given their role as a multiplier in the diffusion of green innovations and their function as a driver of regional sustainability.

5. How do green start-ups perform?

Few studies have investigated the long-term performance of green(er) companies and very limited evidence exists for start-ups. Bjornali and Ellingsen (2014) reviewed the literature on the factors that affect the performance and growth of clean technology start-up firms, a definition of green start-ups that is slightly narrower than in other research. In their review they show that in the 13 articles that they have identified that most focus on external drivers of performance such as policy instrument and none of the studies has a design that would allow a causal link between greenness and performance. In fact, many of the studies ignore individual and firm-specific factors, e.g. characteristics of the clean-tech entrepreneurs and their teams, as well as their networks, that likely drive both greenness and performance.

A likely explanation for the scarcity of performance studies is that it constitutes a central challenge to distinguish correlation from causality. That means, a positive (or negative) correlation between green technology adoptions (or innovation) and company performance does not necessarily imply that the performance is caused by eco-innovation. For established companies we know that more profitable businesses have more slack to finance risky and ambitious projects, including non-environmental R&D and green innovations. Better performing companies may also be able to recruit different types of managers and certain kinds of employees, including those who are more forward-looking and care more about the environment. Identifying the causal impact of green technology or environmental business practices is therefore not straightforward and requires taking into account the timing of activities and addressing the endogeneity problem with econometric techniques.

Bjornali and Ellingsen (2014) also challenge the view that performance should be measured mainly in terms of the environmental and innovative performance of clean-tech start-ups. Instead, it should be measured using standard indicators, allowing conclusions regarding the 'triple bottom line', that is to measure performance using the traditional financial bottom line of a company, i.e. the financial profit, as well as by the company's social responsibility and the company's environmental responsibility. While the first measure is also related to innovativeness and firm growth, which are two standard performance indicators, the last two are rather qualitative in nature and may (or may not) correlate with the first. Some studies emerged after this review had been completed. Meyskens and Carsrud (2013), for example, study the partnership portfolio of 50 green-technology businesses and find that partnership diversity is positively related to venture development, i.e. whether a business plan will be turned into a start-up. This suggests that ecosystems that provide expertise and opportunities for partnering are better breeding grounds for green start-ups. Looking at facilitators within rather outside of companies, Hottenrott et al. (2016) studied the productivity implications of emission-reducing technology in SMEs and found that green innovation may come with a loss of productivity if not combined with organisational innovations that compensate for higher abatement to compliance costs. These insights also stress the need for analysing the performance effects of green innovation in combination with other factors, such as founder's skills, experience and managerial strategies.

While Hottenrott et al.'s (2016) study does not focus on new companies, Leendertse et al. (2020) investigate the performance of sustainable start-ups and document a trade-off between business performance and potential climate impact in the sense that lower business performance comes with higher potential

climate performance. Their insights are based on detailed data from 197 international start-ups that participated in the Climate-KIC accelerator programme in the Netherlands, Germany, Austria, Switzerland and the Nordic countries (Denmark, Norway, Sweden and Finland) and were founded between 2012 and 2016. Their key finding corresponds to the idea that green activities are more attractive – and hence more frequently adopted – in areas where resource-saving also has some economic benefits and the gap between private and social returns is lower. In line with this, the authors also show that this trade-off is context-specific since start-ups can partly escape this pattern by focusing on novel and hardware technologies. In contrast to this, Neumann (2023) investigates the performance of green start-ups using Global Entrepreneurship Monitor data on more than 9500 entrepreneurs from 51 countries, and shows that start-ups with a higher environmental orientation are of higher quality regarding their innovativeness, growth expectations and exports. These results hold at different entrepreneurial stages and across countries.

Goldstein et al. (2020) investigated short-to-medium term (5-10 years) outcomes, such as patenting activity, and business success (as measured by acquisition or initial public offering), survival and venture capital (VC)-raised start-ups that received funding by the US Advanced Research Projects Agency – Energy (ARPA-E) – in 2010. They find that ARPA-E's awardees produced significantly more patents than similar companies. However, while ARPA-E awardees performed better than rejected applicants in terms of their ability to attract VC investment post-award, the likelihood of surviving, of being acquired or going public, they had no advantage over the average similar clean tech company in these dimensions. Unfortunately, the study does not allow any conclusions to be drawn regarding the performance relative to non-clean tech ventures from the same cohort. The findings are nevertheless very useful for understanding barriers to green companies in gaining market traction.

What these existing studies have in common is the lack of a suitable comparison group for the performance assessment. Ideally, we would be able to compare the development of start-ups from the same cohort over time while distinguishing between green and other start-ups. Initial results based on data on start-ups from Germany that participated in the IAB/ZEW Start-up Panel show that there are hardly any performance differences between green (as measured based on the items presented in Figure 1) and other start-ups once the analysis accounts for founder, company and location characteristics. In this analysis sample, 34 % of start-ups were classified as green based on above-average item scores (compare Figure 1). More precisely, firms in both groups perform similarly in terms of likelihoods of sales growth, profitability, exporting or failure. If anything, green companies do show slightly higher employee growth and a higher likelihood of exporting, but the latter difference is small and only weakly significant.

Table 7.1 Differences in performance for green start-ups (Average treatment effects after matching)

Outcome	Sample mean	ATE	Std. Err.	z	P > |z|
Sales growth	3.813	0.539	2.763	0.20	0.845
Employment growth	0.268	0.075	0.038	1.99	0.047
Profits (yes/no)	0.662	0.008	0.014	0.58	0.562
Exports (yes/no)	0.181	0.023	0.014	1.84	0.065
Failure	0.088	-0.001	0.009	-0.07	0.945

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Notes: n = 9.730 (unbalanced panel with firm-year observations). Covariates used in matching: years of industry experience, R&D expenditures, entrepreneurial experience, number of employees, gender distribution in founding team, founding motives, founders' academic education, average founder age, founder team size, industry affiliation, location characteristics, legal form, company age, risk tolerance and Big5 personality traits.

While it is not immediately evident that consumer preferences play a role in green start-up performance – as indicated by no differences in sales growth – the higher employee growth shows that being green may come with advantages in hiring. The (albeit weak) evidence for export orientation may suggest that the markets of green start-ups are less domestically orientated than that of other newly founded businesses.

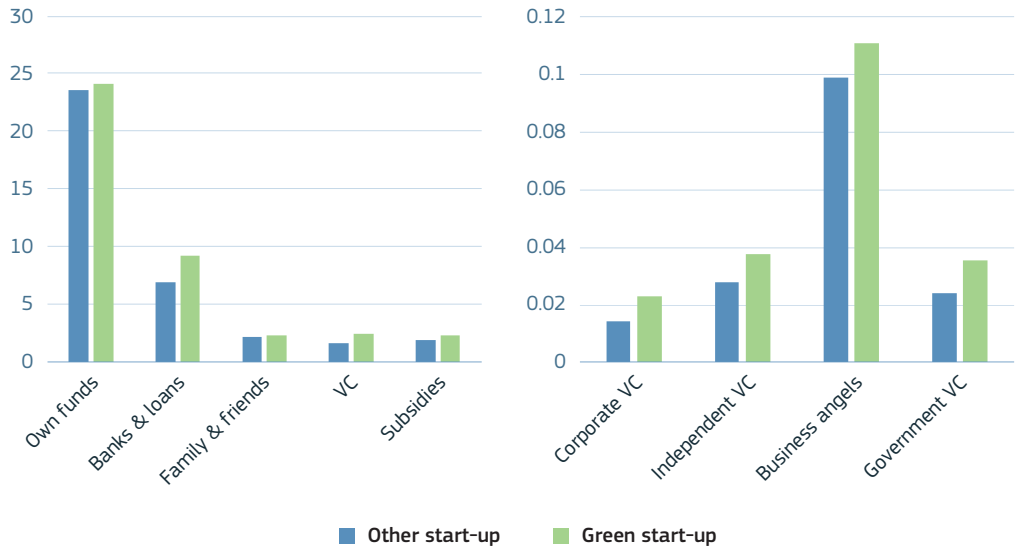
The finding that there are no significant performance differences between green start-ups and other new businesses when accounting for factors that drive green orientation in the first place can be considered good news. Importantly, there does not seem to be a performance penalty for being 'born green'. Thus, if we assume that there are at least some environmental benefits from the existence of these companies and the market introduction of their products, the triple bottom line is likely to be overall positive. The key question that remains unanswered is whether this insight is generalizable across different countries and degrees of greenness. Unfortunately, there is still too little research on the longer-term performance effects of green start-ups and their accumulated impact on emissions or pollution more generally.

Access to financing is generally considered a crucial driver of innovation and firm growth. However, analyses on the access for start-up and growth financing for green versus other start-ups are scarce. Descriptive analysis for start-ups that are part of the IAB-ZEW Start-Up Panel shows that there are indeed some differences in the financing structures between green and other start-ups, defined by whether they offer products that are green in any of the dimensions presented in Figure 1(a). While the patterns are comparable across groups, green companies have similar shares of own financing but higher shares of financing from banks. As one may expect given the recent focus of some policy programmes, they have a higher share of financing from public support programmes. In addition, the share of financing from venture capital investors is, on average, somewhat higher (Figure 6a). When looking more closely into the types of VC providers, we see that the nature of VC differs between green and other start-ups. The analysis based on the definition of green start-ups, as used by Chapman and

Hottenrott (2022) and the classification of investors by Berger and Hottenrott (2021), shows that business angels play a prominent role in the financing of green start-ups; government VC is also more often the source of financing in green start-ups when compared to other new companies (Figure 6b). This descriptive comparison does not account for any structural differences that could also explain differences in the use of financing. When controlling for various other drivers of access to certain types of financing in regression analyses, it turns out that the financing structures are generally not statistically significantly different for green versus other start-ups.

The analysis can, however, not distinguish between successful and unsuccessful attempts of raising financing from the difference sources. It also does not differentiate between the different dimensions of greenness and the degree to which the companies offer products that are more environmentally friendly. The crucial question that remains unanswered is therefore whether green start-ups face hurdles in the success rates of getting access to their desired source of financing and how a potential access penalty relates to the degree of greenness.

Figure 7-6 Financing mix of green versus other start-ups



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Source: IAB-ZEW Start-Up Panel, September 2023 (pooled reference years 2011 to 2019), n = 7.003.

6. How can innovation and entrepreneurship policy support green start-ups?

One important factor that is typically stressed in the context of promoting start-ups from a policy perspective is the provision of seed funding through grants and subsidised loans (Hottenrott and Richstein, 2020; Zhao and Ziedonis, 2020; Berger and Hottenrott, 2021) or through the reduction of organisational or bureaucratic barriers to entry (Colombelli et al., 2020). It is unfortunately, by and large, unknown whether the share of green start-ups in Europe that received some form of public support differs to that of non-green new ventures. From an economic welfare point of view there are good arguments in favour of stronger policy support and specific, targeted programmes such as ARPA-E in the US, but also in favour of more general start-up support schemes. While there is an increasing number of policy initiatives at national levels to promote green start-ups in Europe as well, one challenge in designing such programmes is the definition of what counts as green. Most programmes therefore focus on green-tech, which comprises many relevant sectors but overlooks others. As discussed above, there are broader and narrower definitions. Applying a narrow definition favours start-ups in undeniably green sectors such as renewable energy or recycling. Such a definition, however, may neglect important areas where green innovation is crucial, such as in consumer products, logistics and transportation or construction.

Government support, however, likely plays a crucial role for green start-ups as it does for other entrepreneurship. Regulatory incentives (Berrone et al., 2013) and financial support can both drive and steer entrepreneurial actions. The analysis of green start-ups in Germany indeed illustrates the role played by start-up support programmes and government VC. Green public procurement may also play a role in drawing attention to public and private sector needs (Krieger and Zipperer, 2022). Green public procurement aims at procuring specific goods with lower detrimental effects on the environment throughout a product's life cycle when compared to other goods that serve the same primary function (European Parliament, 2008). In the procurement process, technical specifications can be defined during the different phases, which allows procurers to adjust to technological developments (Appolloni et al., 2019). Technical specifications may include environmental standards or performance requirements such as on a product's energy usage, the carbon footprint of a production process or the use of hazardous substances (European Commission, 2016). Finally, contract performance clauses regulate the monitoring possibilities of public authorities to examine the compliance of the selected awardees with regard to their guaranteed environmental performance. Results presented by Krieger and Zipperer (2022) indeed show that winning public procurement awards with additional environmental selection criteria increases the probability of a company to introduce new and more environmentally friendly products by 20 percentage points, on average. This can be interpreted as a direct impact from the procurement contract while there is no evidence that the company becomes more sustainable overall, which would be reflected in the implementation of more environmentally friendly processes. Given its direct impact, green public procurement is high on the policy agenda. It remains, however, unclear whether new firms react to such incentives in similar ways or whether green public procurement can even trigger new green start-ups. Füner and Krieger (2023) provide some first insights that this might indeed be the case and that procurement opportunities set incentives for green entrepreneurship.

Environmental regulation is moreover a direct lever for altering technology paths. It may be used to create incentives and markets for environmentally beneficial technologies (Gerlagh, 2008; Dechezleprêtre et al., 2011). Industrialised countries have more advanced environmental and climate regulations and some of these regulations have had an impact beyond the regulatory terrain. For example, vehicle emission regulations in the US led to technology sourcing from Japan and Germany (Lanjouw and Mody, 1996). Analyses by Dechezleprêtre et al. (2011) suggest that regulation in China may have spurred technology flows into the country that had some beneficial impact. In sum, however, the effectiveness of regulation in setting incentives for new firm creation is still unclear, especially in light of international competition and different regulatory regimes. Recent numbers, however, suggest that even the expectations about future regulation can incentivise entry as the surge in energy start-ups shows (Gottschalk and Hottenrott, 2024).

Considering environmental policies more generally, as one of the most comprehensive studies, Cojoianu et al. (2020) investigate how different types of environmental policies affect new firm formation in green (low carbon), brown (fossil fuel) and grey (unrelated to natural resources) technologies across 24 OECD countries. Their results show that that regional environmental knowledge is a key contributor to the creation of green start-ups. They also find evidence for positive externalities that these firms create because 'grey industries' also benefit from the improved availability of start-up financing in regions where new environmental knowledge is created. Another key result is that more stringent environmental policy regimes negatively impact the creation of new ventures overall, though the effect is stronger for new fossil fuel-based companies. However, while some policies appear to discourage entry, there seems to be a positive correlation between policy stringency and the availability of financing across sectors. In particular, feed-in-tariffs and emission standards are significantly and positively related to new regional green venture capital financing, across different investment stages and green sub-markets.

7. Implications and conclusion

Recognising the challenges and need for action to reduce the negative impacts of climate change is of central importance. Policies that promote incentives and provide support to overcome technological and market hurdles play a fundamental role. Achieving this goal has been high on the policy agenda for many years now (European Commission, 2005, 2011, 2012) and there is some evidence that green start-ups are becoming relevant agents in the transformation process.

The insight that the green transformation requires radical and fundamental innovations puts the spotlight on green start-ups that develop and introduce more innovations with environmental benefits and adopt more sustainable business practices. The evidence, however, also indicates that in order to increase the number and performance of green start-ups for a transition to a low carbon economy, the existing focus on influencing objective decision-making processes of founders alone might be insufficient. Instead, policymakers may need to account for the innate business climate that enables founders to successfully pursue their ideas. The multiple externalities related to green entrepreneurship require special attention to hurdles that prevent green ideas from being implemented. In addition, policymakers may be able to take advantage of helpful predispositions (e.g. high levels of openness and extraversion) by targeting support but may need to provide additional intervention and support to overcome the effects of the negative predispositions of other traits (e.g. high levels of neuroticism). Second, in an environment increasingly pushing organisations and start-ups to be green, founders and entrepreneurs need to be cognizant of the environmental implications of their personality traits, and potentially take steps to overcome the unhelpful environmental dispositions of traits like neuroticism.

The definition of green start-ups used throughout this chapter considers companies to be green if they offer environmentally friendly products or services that either directly benefit the environment or reduce negative impacts as compared to established products and services. This definition also comprises innovation on processes, company organisation and logistics, or other management practices (including human resources, finances, and sales). This relative broad definition allows the inclusion of start-ups into the definition without having to focus on specific technologies such as clean energy, materials or recycling, which may overlook more subtle green innovation in all other sectors.

In light of the need to transition entire economies toward more sustainable practices and outcomes, it seems important to incentivise green entrepreneurship across all sectors, including services and low-tech industries where the green potential may mainly lie in greener processes.

While the role of start-ups in the green transition is likely to be of fundamental importance, previous research, however, has mainly focused on green innovation in larger established corporations. There is also a substantial lack of studies that investigate 1) the causal impact of policy instruments and programmes on the formation of new green start-ups, 2) how being green is related to start-up performance, and 3) whether there are differences depending on the dimension or degree of 'greenness'. From a policy perspective, the missing insights on green start-ups are problematic as it remains unclear how they contribute to the invention and diffusion of different technologies, business practices or the spread of informal environmental standards. While there is a consensus on the role of start-ups in inno-

vation more generally (Aghion and Howitt, 1992; Wennekers and Thurik, 1999; Carree and Thurik, 2003; Audretsch et al., 2006), we know little about whether and how this extends to green innovation in the form of new products, services and business practices.

In the upcoming decades, green start-ups could potentially be of even greater importance as a driver of sustainable regional development and regional employment dynamics (Fritsch and Schindele, 2011; Dejardin and Fritsch, 2011). Therefore, understanding the dynamics of the creation of green start-ups, their locations and international mobility is crucial for economic policy. Such ambitious initiatives call for larger-scale systematic studies of new green business creation across Europe and beyond.

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