Entrepreneurs for a low carbon world

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Entrepreneurs for a low carbon world: How environmental knowledge and policy shape the creation and financing of green start-ups

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ABSTRACT

We investigate how different types of environmental policies and new regional environmental knowledge affect new venture creation in and financing of green (low carbon), brown (fossil fuel) and gray (unrelated to natural resources) technologies across 24 OECD countries and 293 regions over the period 2001-13. We find that new regional environmental knowledge positively impacts new venture creation in green technologies, and moderately in gray industries. Gray industries also benefit from enhanced start-up financing in regions where new environmental knowledge is created, confirming that environmental knowledge creation yields positive externalities beyond the green sector. We also find that a more stringent environmental policy regime negatively impacts the creation of new ventures across sectors, but most prominently, it discourages new fossil fuel ventures. However, once entrepreneurs decide to start a new business, stringent environmental policies have on aggregate a positive effect on new venture financing across sectors, particularly through feed-in-tariffs and emission standards.

1. Introduction

The increased societal attention and urgency towards combating climate change and transitioning to a low carbon, resource efficient economy has prompted many actors around the globe to seek solutions to solving environmental issues. In the past decade, entrepreneurs have become instrumental in solving our most pressing societal challenges through business model, technological, financial and social innovation (Malen and Marcus, 2017; York and Venkataraman, 2010). The underlying mechanisms which enable new technology emergence across time and space have been the focus of both innovation academics and institutional theorists (Vedula et al., 2018). Innovation studies draw the attention to contextual knowledge as one of the most important factors affecting the creation of new firms (Acs et al., 2009; Audretsch, 1995; Audretsch and Keilbach, 2007). On the other hand, institutional theorists have highlighted how entrepreneurs are influenced by government policy and regional social norms (Dean and McMullen, 2007; Mason and Brown, 2013; Vedula et al., 2018; York and Lenox, 2014; Zietsma et al., 2018), in both an enabling and constraining way (Bruton et al., 2010).

Technology and innovation studies, through the lens of the knowledge spillover theory of entrepreneurship (KSTE), have argued that new environmental knowledge created but uncommercialized in incumbent companies or research organisations is the main source of entrepreneurial opportunity in the low carbon energy transition. These are mainly empirical studies at the regional level within a single country, predominantly across the US (Malen and Marcus, 2017; Vedula et al., 2018) and Italy (Colombelli and Quatraro, 2017). While this initial evidence is helpful in framing new knowledge creation as an important determinant of green entrepreneurship, we know little whether this insight applies across different green technologies as well as whether new environmental knowledge creation has beneficial

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spillover effects in fostering start-ups beyond the green sector, such as in industries without an environmental goal, or in industries with large environmental externalities.

On the other hand, institutional theorists have argued that the limits of entrepreneurial opportunities, and consequently new venture creation, are defined by the institutional environment (Aldrich, 1990; Bruton et al., 2010). However, the effects of the institutional environment on emerging industries can be highly heterogenous as it can both encourage new venture creation through, for example, market design incentives, but can also hinder new founding rates through an overly prescriptive and/or restrictive regulation (Bruton et al., 2010). So far, studies approaching green entrepreneurship from a formal institutional angle have linked environmental policy with new venture creation mainly through an empirical test linking the presence, but not the stringency, of environmental policies with green start-up creation or financing (Criscuolo and Menon, 2015; Sunny and Shu, 2017; York and Lenox, 2014). Until recently, the unavailability of cross-country environmental stringency datasets means that the literature provides qualitative assessments on how green entrepreneurs perceive environmental policy (Zietsma et al., 2018). Although the study of Georgallis and Durand (2017) is one of the few who considers policy generosity and coherence in the study of the entry and growth of the European solar photovoltaic industry, we know very little about how differences in the level of stringency of different environmental policy instruments affect new venture creation and start-up financing in different low carbon technologies, and whether these are indeed generalisable at the sector level.

To understand this heterogeneity, we seek to answer three underexplored questions in the literature: *What is the impact of new environmental knowledge creation and different environmental policy instruments on green venture founding rates and financing and how do these vary at the green sub-sectoral level? Does new environmental knowledge creation spill over into the creation and financing of new start-ups outside the green sector?* Hence, similarly to Feldman et al. (2019), Moeen and Agarwal (2017), and Petty and Gruber (2011) we employ an exploratory research design that allows for a detailed investigation of our questions, without committing to specific hypotheses. This type of research design allows for the testing of the limits of theory by focusing on granularity and accuracy, but also allows for the testing of generalisability and provides a bedrock for new theoretical development (Petty and Gruber, 2011), particularly in the context of dynamic phenomena such as entrepreneurship entry and financing.

In this light, our study is grounded in and makes several contributions to the innovation literature and institutional theory. Our paper provides cross-country, cross-regional and cross-sectoral evidence by covering green, gray and brown entrepreneurship entry and financing across 24 OECD countries and 293 regions from 2001 -2013[1]. We find that new environmental knowledge creation at the regional level is highly correlated with the creation of green start-ups, moderately correlated with gray start-ups and unrelated to brown start-ups. Our findings also show that new regional environmental knowledge is related to increased gray venture funding, which supports the fact that environmental knowledge yields positive externalities across sectors. As far as policy impact is concerned, we show that the more stringent environmental policies are in a country, the less new brown ventures emerge[2]. We further find that environment related R&D subsidies have a negative impact on green start-up entry but are unrelated to the financing of green start-ups. Feed-in-tariffs and emission standards emerge as the main catalyst for increased investment in green start-ups, which is also confirmed across the majority of green sub-sectors as well as across gray start-ups. Our study shows that environmental policy plays an increasingly important role for the financing of green start-ups but less so in the decision-making of entrepreneurs to enter the sector in the first place. We explain these findings through the lens of institutional theory and KSTE, and also provide avenues for further theoretical developments by examining the exceptions that emerge in our study, which do not necessarily conform with existing theory. These include furthering our understanding with respect to the differences and characteristics of knowledge spillovers which are relevant for entrepreneurs prior to founding a new venture, as compared to knowledge spillovers that occur post venture founding that may influence the start-up financing process. Finally, our paper expands on the literature on institutional theory and entrepreneurship and shows that regulatory interventions which explicitly penalise incumbents (e.g. through market taxes or emissions trading schemes), do not necessarily translate into entrepreneurship opportunities, but rather these need to be followed by additional policies which specifically target green technologies (e.g. feed-in-tariffs).

This paper is structured as follows. In Section 2, we provide the theoretical background that led us to framing our main research questions. Section 3 discusses our empirical model, data collection and preparation. Section 4 provides descriptive statistics of our panel dataset, while Section 5 outlines the results of our empirical investigation. Section 6 discusses our results in relation to theory and provides implications for theory development as well as practice.

2. Theoretical background and research questions framing

2.1. New environmental knowledge, green venture creation and financing

In seeking to explain the spatial distribution of new green venture entry and financing, we turn our attention to the insights provided by entrepreneurship scholars and knowledge theorists, who have attributed the creation of new firms to the entrepreneur's ability to coordinate a range of inputs, including heterogenous knowledge about technology, people and processes (Alvarez and Busenitz, 2007, 2001). But where does new knowledge related to environmental management and low carbon technologies come from and how do potential entrepreneurs become aware of its potential? The knowledge spillover theory of entrepreneurship proposes that the main sources of (green) entrepreneurship opportunities are new ideas and knowledge created in incumbent firms, universities, research organisations but left uncommercialized, largely due to the inherent uncertainty of the payoff associated with pursuing commercial opportunities derived from new knowledge (Agarwal et al., 2010; Alvarez and Barney, 2005; Audretsch and Keilbach, 2007; Audretsch and Lehmann, 2005;

[1] In this study, we refer to green entrepreneurship as the creation of new ventures that may pursue both environmental and economic goals (Isaak, 2016; York et al., 2016), but which are closely related to or operating within the low carbon energy value chain. These are limited to start-ups in 8 green energy subsectors: battery storage and fuel cells, biofuels, environmental data, energy efficiency, electric vehicles and low carbon mobility solutions, low carbon grid infrastructure, renewable energy generation and low carbon materials R&D. The term “gray entrepreneurs” is used to refer to entrepreneurs in industries for which environmental factors are neither major risks nor opportunities (e.g. software start-ups) although they may rely on natural resources. Finally, “brown” start-ups are those that are likely to be heavily impacted by more stringent environmental policies due to their reliance on natural resources and environmental externalities that they produce (e.g. oil and gas entrepreneurs). We explain in more depth in Section 3 how the sub-sector green classification has been used to arrive at our start-up dataset.

[2] The term “environmental policy stringency” is defined as both: “a higher, explicit or implicit, cost of polluting or environmentally harmful behaviour […] for instruments like taxes” (Botta and Koźluk, 2014, pp. 14) as well as incentives for the development of environmental technologies and processes such as feed-in-tariffs or R&D subsidies (Appendix A3). We study the effect of stringency of individual policy instruments as constructed by the OECD (environmental taxes, trading schemes, feed-in-tariffs, emission standards and R&D subsidies) on entrepreneurship outcomes (Section 3).

Colombelli and Quatraro, 2017; Vedula et al., 2018). Thus, the entrepreneurship opportunity arises from an expected valuation assymetry of uncommercialised knowledge between those who create knowledge and potential entrepreneurs (Acs et al., 2009; Audretsch and Keilbach, 2007). Environmental-specific knowledge, however, may be more complex and sophisticated than the general knowledge employed in the context of conventional sectors (Cainelli et al., 2015; Horbach et al., 2013). Scholars have further argued that the incentive to produce green knowledge is unusual, as it is often characterized by the "double externality" issue, which has to do with the fact that green knowledge has positive externalities not only in the innovation stage but also in the diffusion stage, by reducing environmental harm compared to conventional technologies (Cainelli et al., 2015; Rennings, 2000). But regardless of the incentives to produce green knowledge in the first place, KSTE contends that the higher the new knowledge pool for the green sector is, the higher the number of green entrepreneurial opportunities becomes (Colombelli and Quatraro, 2017; Giudici et al., 2017; Sunny and Shu, 2017; Vedula et al., 2018).

Preliminary evidence from Italian regions shows that this is indeed the case (Colombelli and Quatraro, 2017; Giudici et al., 2017), with new green ventures being positively influenced not only by the creation of more green knowledge, but also by the creation of knowledge from diverse and heterogenous knowledge sources from complementary fields (Colombelli and Quatraro, 2017). Studies focusing on the US green entrepreneurship sector also confirm the assertion of KSTE (Sunny and Shu, 2017; Vedula et al., 2018), and further illustrate that regions which feature strong pro-environmental social norms tend to produce more green entrepreneurs when the regional knowledge base is less specialised in green technologies, thus drawing the attention that the impact of the knowledge base on entrepreneurship entry can be moderated by other factors like regional institutional logics (Vedula et al., 2018; York and Lenox, 2014). But besides this initial evidence across Italy and the US, there is no comprehensive cross-country and cross-regional study that tests the relationship between new environmental knowledge creation and new green start-up entry. Hence, the first question our study seeks to answer is:

Question 1: To what extent does new environmental knowledge creation influence new green venture creation?

Potential entrepreneurs can come in contact with new and uncommercialised knowledge "[…] by participation in formal R&D partnerships as well as through supplier–customer relationships, professional associations and mobile human capital" (Feldman and Kelley, 2006, pp. 1510) among other channels. Given that organisational boundaries are to a certain degree "porous", knowledge created within organisations is non-excludable, unlike other inputs into economic activity (Arrow, 1962; Audretsch and Keilbach, 2007; Vedula et al., 2018). Knowledge and innovation partnerships of green firms tend to be very diverse, ranging from firms across the full spectrum of sectors, research organizations, governments and not-for-profit organizations (Doblinger et al., 2019). This implies that green knowledge spillovers into entrepreneurship may expand past the creation of new green ventures, into the creation of gray and even brown ventures. This hypothesis has yet to be tested, as the literature has so far focused on showing that: i) based on patent citations, green knowledge spillovers are more prominent that spillovers from brown knowledge across sectors (Dechezleprêtre et al., 2013), ii) brown knowledge creation does not lead to new green venture entry (Colombelli and Quatraro, 2017) and that iii) green energy-related knowledge generated by firms is more widely cited compared to new conventional knowledge generated by the same firms (based on patent data) (Popp and Newell, 2012). Hence, we further seek to answer the following question:

Question 2: Does new green knowledge creation spill over into the creation of gray and brown ventures?

Beyond the impact of new knowledge creation on new venture entry, the literature tells us little about whether the benefits of regional green knowledge pools also extend to the financing of new ventures. The regional context is highly informative in the context of the study of entrepreneurship in green technologies not only because knowledge spillovers tend to manifest themselves at this level, but also because venture capitalists and private equity houses which have been the first to back these technologies are known to operate in geographically dense social networks for the benefit of both sourcing investment opportunities and scaling promising start-ups (Knight, 2012; Martin et al., 2002). Start-up financing provides further context to an entrepreneurship ecosystem, by signalling the high-growth scaling potential of new ventures. This is ever more important in the context of the low carbon transition, given both the investment needs of the sector and the imperative for timely scale-up of green solutions across geographies (BNEF, 2019; Gaddy et al., 2017; Knight, 2012). Knowledge spillovers into entrepreneurship continue past the moment of founding of a new company, through the experience and knowledge that founders bring (Feldman et al., 2019), through the hiring of new employees (Qian et al., 2013) and the strategic partnerships that companies make (Doblinger et al., 2019). In this light, we seek to answer whether new green knowledge pools generated outside new start-ups influence their financing.

Question 3: Does new regional green knowledge creation result in increased financing for green, gray or brown ventures?

2.2. Environmental policy stringency and green entrepreneurship

Since entrepreneurs are seen as job creators and celebrated as key agents of economic growth (Acs et al., 2016), policy makers have taken great interest in tailoring public policies that promote entrepreneurship (Shane, 2009). While public policies targeted at enabling high-growth entrepreneurship have been explored in more depth (Grilli and Murtinu, 2014; Lerner, 2010; Mason and Brown, 2013), it is less understood how entrepreneurs in emerging high-tech sectors are impacted by government policies which aim to correct environment-related market failures.

Institutional theory suggests that organisations are both grounded in and shaped by the regulatory, social and cultural environments they operate in (Bruton et al., 2010; Scott, 1995). Out of these three pillars of institutional theory, summarised by Scott (2007), we focus on the regulatory pillar, which originates in the idea that institutions define, monitor and enforce the rules of the game (Bruton et al., 2010). These regulatory developments do not come only from government legislation, but also industrial agreements and standards. Scholars acknowledge the continuum between formal and informal mechanisms of the regulative pillar, ranging from ostracism for non-compliance to severe legal implications for breaking the law (Hoepner et al., 2019).

Entrepreneurship is a phenomena which is sensitive to the direct action of governments, particularly in relation to the allocation of rewards (Baumol et al., 2009; Bruton et al., 2010). On the one hand, governments can encourage entrepreneurship through regulation that legitimises their business models, or regulation that increases the disruption potential of incumbent structures among others (Christensen et al., 2018; Scott, 2007). Theory also suggests that a well-developed institutional environment with overly prescriptive regulations where entrepreneurs are burdened with too many rules and procedures can also be detrimental to the founding of new ventures (Klapper et al., 2006). The idea that regulation should not necessarily stifle innovation goes back to Hicks (1932), and was adapted by Porter (1991) to suggest that environmental policy should not hamper innovation. The large literature that has resulted in the past 28 years has broadly supported the claim, but have largely focused on the US manufacturing industries, with more recent studies expanding the geographic and sectoral coverage (Ambec et al., 2013; Brunnermeier and Cohen, 2003; Dechezleprêtre and Sato, 2017; Jaffe and Palmer, 1997). Hence, there is very limited evidence related to the influence of environmental policy on entrepreneurship, pertaining to both the founding of new venture as well as their financing and growth process across different policy environments.

While the emergence of new industries is partly attributed to policy, recent evidence also points to the fact that it is possible that policy intervention does not occur by default across all emergent industries. By contrast, policy intervention tends to occur more in emerging industries that first reach a critical mass of actors with a coherent identity (Georgallis et al., 2018). Such has been the case for the European solar industry and their influence on the introduction of feed-in-tariffs (Georgallis et al., 2018). In the absence of institutions, new entrants can still find opportunities as “institutional entrepreneurs”, by working towards the organisation of new institutions, or the transformation of existing ones, towards providing further legitimacy and support for the emerging sector that new entrants operate in (Alvarez et al., 2015; Bruton et al., 2010; Dean and McMullen, 2007; DiMaggio, 1988).

The relationship between environmental policy and entrepreneurs is further complicated by other economic agents. Zietsma et al. (2018) show that incumbents can use their political capital to lobby and influence policymakers towards a policy environment favourable to incumbent structures rather than new entrants. Similarly, Ball and Kittler (2017) provide evidence from interviews with environmental entrepreneurs from the UK, France and Germany and shows that even though more stringent environmental policies (e.g. market taxes) or support mechanisms for low carbon investment like emissions trading schemes have been introduced, these were more effective in supporting large diversified incumbents and utilities rather than promoting entrepreneurship. Entrepreneurs are hence likely to be trapped in what Pacheco et al. (2010) calls “the green prison”, where they face a competitive disadvantage compared to incumbents in conditions where market incentives are set to favour the latter. Green entrepreneurs then have the difficult task of seeking to alter the rules of the game, by trying to change norms, property rights and legislation that would reward environmentally friendly practices (Dean and McMullen, 2007; Pacheco et al., 2010). Sometimes, green entrepreneurs can benefit from the visibility and influence of their financial backers. For example, to the biofuel companies Range Fuels and LanzaTech, which benefited from the public policy engagement of their common venture capital (VC) backer, Khosla Ventures, which alongside other high profile VC funders such as KPCB have engaged in lobbying for favourable policy change towards sustainable energy issues (Center for Responsive Politics, 2018; Pacheco et al., 2010).

While our study tests the impact of the regulatory environment on new venture formation and financing, several studies have confirmed that local social norms and values, corresponding to the normative pillar of institutional theory described by Scott (1995), are more important in shaping new venture entry in emerging sectors, whether in the context of green buildings (York and Lenox, 2014), renewable energy (Sine and Lee, 2009; Vedula et al., 2018) or responsible investment (Hoepner et al., 2019). It is unclear however whether and the mechanism through which the influence of the regulatory environment increases during start-up scaling and financing, as start-ups go beyond building legitimacy towards the building and commercialisation of new products and services where policy discontinuity can be detrimental to the growth of new entrants (Georgallis and Durand, 2017). The recent literature on venture capital investing suggests that formal institutions are an important determinant of the variation of VC financing across countries and regions, but moderated by the cultural setting (Jeng and Wells, 2000; Li and Zahra, 2012). In this light, the final question we explore is:

Question 4: How does environmental policy stringency shape the entry and financing of green, gray and brown entrepreneurs?

3. Research design, data and methodology

3.1. Research design

In order to answer the questions set out in the previous section, which links green entrepreneurship with new regional environmental knowledge creation and environmental policy stringency, we examine the rationale behind the choice of dependent and independent variables, which we integrate in our statistical models further explained in Section 3.2.

In trying to proxy for new regional entrepreneurship, there is a wide agreement in the entrepreneurship and innovation literature that one way to measure entrepreneurship outcomes is through the count of new start-ups in a given area, whether at city, region or national level (Audretsch and Lehmann, 2005; Vedula et al., 2018; York and Lenox, 2014). Unless the variable seeks to quantify general entrepreneurship by using the entire business registry data related to a particular region, then researchers would have to choose a sample of new start-ups whose entry count is representative for the phenomena studied. In addition, a measure based on counts does not necessarily imply the quality or growth potential of entrepreneurship in a given region, hence, one requires additional measures for entrepreneurship outcomes. For this reason, we select VC-backed or VC seeking start-ups proxied by their appearance in the Crunchbase dataset, based on which we build a regional count of green entrepreneurs by manually checking the websites of those start-ups that Crunchbase tags as related to green energy as well as from additional datasets. Next, we complement it with a second measure, regional VC financing, which further enhance our understanding about which regions have the start-ups with the highest perceived growth potential.

In order to link these two entrepreneurship measures with environmental knowledge, we also require a new knowledge creation proxy which can be reliably measured across our 24 countries and 293 regions. Given the challenge to measure tacit knowledge and when its creation occurs, we rely on a measure of codified knowledge creation in space, by using the location of the inventors who file patent applications in the area of green energy. The green energy sector lends itself to being analysed through patents, as it is a sector that relies on the global patent system for IP protection. This is in contrast to other sectors, such as the financial sector, whose innovations are largely unpatented. The reliance of green technologies on the global patent system is also illustrated by the fact that the European Patent Office has introduced a new classification for sustainable energy technologies[3]. Hence, we use the patent filing as an approximate date which is closest to the actual creation of new environment-related knowledge by an inventor or group of inventors.

Finally, to understand the link between environmental policy and entrepreneurship, we resort to using a novel measure of cross-country environmental policy stringency developed by the OECD (Botta and Koźluk, 2014), which is superior to proxies of environmental policies which only rely on either dummy variables quantifying the presence of a type of policy, or indeed some that rely on a count of policies which apply to a certain region. We explain the environmental policy stringency measure in more depth in the next section.

3.2. Dependent variables

New regional VC-backed and VC-seeking technology start-up ventures

The dependent variable is comprised of the yearly count of new high technology ventures across 293 regions in 24 OECD countries founded between 2001 - 2013. To illustrate how different entrepreneurship sectors are impacted by different government policies, we study new

[3] https://www.epo.org/news-issues/issues/classification/classification.html

entries in green, brown and gray sectors. We use a paid database subscription to Crunchbase[4], a leading provider of intelligence for investors in technology start-ups around the world, to map the high-tech, VC-backed start-ups founded between 2000 – 2016 (176,994 in total) by region and sector.

To identify the sectors of interest that new entrants operate in, we mapped the technology sector provided by Crunchbase with the Sustainable Industry Classification System (SICS) provided by the Sustainability Accounting Standards Board (SASB). We have also reviewed the green sub-sector classifications used in literature (BNEF, 2019; Criscuolo and Menon, 2015; Gaddy et al., 2017; Vedula et al., 2018) as well as those from specialised research providers such as the Cleantech Group[5], and we narrow the definition of green start-ups as those operating in any of the following 8 green technology subsegments: battery storage and fuel cells, biofuels, environmental data, energy efficiency, electric vehicles and low carbon mobility solutions, low carbon grid infrastructure, renewable energy generation and low carbon materials R&D). We provide further detail in Table 1.

To further enhance the dataset, we included a database of 6,831 corporations which have environmental and social aims in their articles of incorporation (list of B corporations and public benefit corporations provided by B Lab[6]) which we used to further identify companies in the green sector in Crunchbase. This process resulted in the identification of 4,201 potentially green start-ups, founded between 2000 – 2016. We manually classify these 4,201 companies through researching their websites, news and Crunchbase profiles and restrain the sample over the period 2001 – 2013, over 24 countries for our proposed statistical analysis. In cases where the start-ups may have been closed or acquired and hence had valid website, we investigated historical business registry data from different countries or investigated their archived websites at a given point in time using the Internet Archive Wayback Machine[7], a collection of over 357 billion web pages saved over time. By narrowing the sample over the 2001 – 2013 period and categorising green start-ups over the 8 green sub-markets, the resulting dataset consists of 2,468 green start-ups.

We use the yearly count of new entrants by technology and region. The mapping of all the VC-backed or VC-seeking start-ups by region was done manually using a company's incorporation address and a mapping tool provided by the OECD which allows us to match company addresses with Territorial Level 2 or TL2 regions of OECD countries (OECD, 2018). This allows for comparability internationally given that national statistical offices use the OECD classification to collect different policy relevant datasets and governments use these to set regional policies.

Green start-up investment

Using the location of the sample of VC-backed green start-ups shortlist identified above we classify green start-up funding rounds at the regional level. We retrieve all the funding rounds from Crunchbase for green start-ups from the date of founding till the date of their IPO, the date the start-ups are acquired or closed, or till 2013 (in case the company is still in operation). Hence, we identify 2,505 founding rounds across different fundraising stage types including: early stage venture (seed funding, angel investing, series A and B), late stage venture (series C to G), venture debt, private equity, grants, crowdfunding and corporate venture capital. This allows us to conduct statistical analysis on overall green start-up funding, as well as across the early and late stage funding rounds, private equity and venture debt deals which are the most comprehensive funding subcategories that Crunchbase collects.

3.3. Independent variables

The variables below seek to capture new environmental knowledge per region (as measured by patent applications) and environmental policy stringency (as measured by OECD environmental indices).

Environmental knowledge

We use regional patent applications as a proxy for new regional environmental knowledge. Regional green patent data was collected from the OECD REGPAT database which allows for quantification of the innovation output over more than 2,000 TL3 regions in the OECD and across several technologies including environmental technologies (Maraut et al., 2008). We aggregate these to the TL2 level to match the start-up dataset. The OECD employs robust patent search methodologies to identify all the patent applications to the EPO, USPTO and JPO as well as those filed under the Patent Cooperation Treaty (PCT) (OECD, 2016). The patents belong to six top-level environmental technology categories: i) capture, storage, sequestration or disposal of greenhouse gases, ii) climate change mitigation technologies related to buildings, iii) climate change mitigation technologies related to energy generation, transmission or distribution, iv) climate change mitigation technologies related to transportation, v) environmental management and vi) water-related adaptation technologies (Haščič and Migotto, 2015). We use these disaggregation level to distinguish between different types of environmental knowledge as indicated in our hypotheses.

Patents are an imperfect measure of regional or country innovation given that it cannot capture those innovations that are not patentable or inventions that are not patented by their inventors. In addition to this, not all patents are used for commercial purposes. However, patent data offer the intermediate outputs of the innovation cycle, they are widely available and can be easily classified to match the technology sector of interest. In accordance with Fabrizi et al. (2018), we use environmental patent applications rather than patents granted since the patent application event reflects much more accurately the timeframe of new knowledge creation. The patent data is further grouped by the region of residence of the inventors and are represented as a fractional count of the country's patents.

OECD environmental policy stringency

The policy variables we use in this study are the economy wide environmental policy stringency (EPS) indices constructed by the OECD which cover 29 OECD countries between 1990 – 2012. The EPS indices are obtained from granular indicators at the individual instrument level which are aggregated in five policy instrument categories: taxes, trading schemes, feed-in-tariffs, emission standards and R&D subsidies (Table 2). The OECD first scores every granular policy instrument between 0 and 6 which reflects the relative stringency across countries of a particular policy instrument (e.g. CO_2 emissions tax), which are then assigned equal weights to compose aggregate indices by policy instrument types (e.g. taxes, see Appendix A.3). We also include an aggregate EPS indicator which is constructed by the OECD through taking the arithmetic mean of the policy instrument indicators (Table 2).

We study the effects of country level environmental policies on regional entrepreneurship given that environmental policy decision making is made at the national level whereas entrepreneurship is highly dependent on clusters and regional characteristics. For federal countries in our dataset (e.g. US States or Canadian Provinces), the country level EPS at different levels is obtained as a weighted average of state-level EPS based on a state's share of a country's total energy generation. In this way the index also takes into account the relative influence of regions where these do have a real influence on regional environmental policy. The indices are useful for comparing their relative effects across countries but are not built to reflect the relative stringency across different types of policy instruments (e.g. a score of 4.5 of environmental tax stringency is not comparable with a score of 4.5 in the trading schemes stringency category).

[4] https://www.crunchbase.com/
[5] https://www.cleantech.com/i3/
[6] https://www.bcorporation.net/
[7] https://archive.org/web/

Table 1
Industry classification matching. Source: authors

SASB industry classification	Crunchbase classification	Green submarkets shortlist*	Paper terminology
Renewable Resources, Alternative Energy & Infrastructure (Utilities and Waste Management).	Battery, Biofuel, Biomass Energy, Clean Energy, CleanTech, Electric Vehicle, Electrical Distribution, Energy Efficiency, Energy Management, Energy Storage, Environmental Consulting, Environmental Engineering, Fuel Cell, Green Building, Green Consumer Goods, GreenTech, Paper Manufacturing, Pollution Control, Power Grid, Renewable Energy, Smart Building, Smart Home, Solar, Sustainability, Timber, Waste Management, Water, Water Purification, Water Transportation, Wind Energy, Wood Processing, Recycling	1 Battery Storage and Fuel Cells (Battery) 2 Biofuels 3 Environmental Data, Software, Finance, Energy Suppliers & Consultancy (DSFSC) 4 Energy Efficiency (Eeff) 5 Electric Vehicles and Low Carbon Mobility Solutions (EV). 6 Grid, Electrical Infrastructure and Power Conversion (Grid) 7 Renewable Energy Generation (Generation) 8 Low Carbon Materials R&D and Manufacturing (Materials)	Green

*The green submarkets shortlist was obtained by manually classifying 4,201 potentially green start-ups which resulted from matching the Crunchbase classification with the SASB industry classification (founded between 2000 – 2016). The manual classification resulted in 2,689 VC backed green start-ups founded between 2001 -2013, split across the 8 green sub-market categories above.

SASB Industry Classification	**Crunchbase Classification**	**Green submarkets shortlist***	**Paper terminology**
Non-Renewable Resources	Fossil Fuels, Fuel, Mineral, Mining Technology, Natural Resources, Oil and Gas, Precious Metals, Mining	Not Applicable	Brown
Healthcare, Financials, Technology and Communications, Transportation, Services, Consumption, Infrastructure (Infrastructure and Real Estate).	Software, Biotech, Healthcare, Telecommunications, Real Estate and other sectors excluding the ones above.	Not Applicable	Gray

Table 2
Environmental policy stringency indices. Source: Botta and Koźluk (2014).

EPS policy instrument aggregation	EPS granular policy instruments
Taxes	CO_2, NO_x, SO_x, Diesel
Trading schemes	CO_2, Renewable Energy Certificates, Energy Efficiency Certificates.
Feed-in-Tariffs (FITs)	Solar, Wind
Standards	Emission Limit Values: NO_x, SO_x and PM_x, and Sulphur content limit.
R&D Subsidies	Government R&D Expenditure on Renewable Energy

3. 4. Control variables

Further control variables for which we have strong theoretical grounding to include are listed in Table 3 alongside with the dependent and key independent variables.

3.5. Model specification

We use two different models to account for regional venture entry vs. regional venture investment. For all the models, regressors are lagged one year to alleviate some potential concerns with reverse causality. Although our start-up dataset extends to 2016, one of our key independent variables, environmental policy stringency is only available to 2012, and our regional patent dataset is available to up to 2013. Hence, our analysis is conducted at the regional level, with data organised in a balanced panel between 2001 – 2013.

Regional start-up entry

The start-up entry dependent variables across of three sectors (green, brown and gray) is a non-negative count integer. The model residuals exhibited overdispersion and violated normality assumptions and hence, in line with the work of York and Lenox (2014), we employ a random effects model. Allison and Waterman (2002) show that a fixed effects estimator is biased for a negative binomial model and cannot control for varying covariates. To further control for temporal variations in our models, we include year dummy variables which we do not report in the results. The standard errors of all models are clustered at the regional level (Kölbel et al., 2017; Petersen, 2008). The approach of Kölbel et al. (2017) controls for both panel autocorrelation issues and cross-panel IV correlations. For robustness purposes, we also run zero-inflated negative binomial models which confirm that our results are consistent. To alleviate concerns regarding reverse causality, we use the method proposed by (Godfrey et al., 2020). The method is a Granger-style reverse causality minimisation procedure, which can be used in the absence of a natural experiment when reverse causality, as in our case, is the most concerning aspect of endogeneity (please see the Online Appendix for a description of Godfrey et al.'s method).

The full log-linear models we estimate can be expressed by the following equation at different policy granularity levels, where μ_t is the time effect and $\varepsilon_{i,t}$ is the stochastic error.

$$
\begin{aligned}
&New\ \ Ventures_{i,t}\\
&= \exp[(\beta_1{*}\ln(Environmental\ \ Knowledge_{i,t-1}) + \beta_2{*}ln(EPS_{i,t-1}) +\\
&\beta_3{*}ln(Start-Up\ \ Funding_{i,t-1}) + \ \beta_4{*}ln(GDP\ \ per\ \ Capita_{i,t-1}) +\\
&\beta_5{*}ln(Ren\ \ Energy\ \ \%\ \ of\ \ Tot\ \ Energy_{i,t-1}) + \beta_6{*}ln(Renewable\ \ Industry\ \ Tilt_{i,t-1})\\
&+ \beta_7{*}ln(Regional\ \ Research\ \ Institutes_{i,t-1}) + \mu_t + \varepsilon_{i,t}]
\end{aligned}
$$

Regional green start-up investment

We also build a balanced regional panel between 2001 – 2013, with the main independent variable being green start-up investment, as an overall investment figure as well as disaggregated by green sub-sectors and investment stage. We employ a two-way log normal OLS regression model which accounts for country and year fixed effects and clusters model standard errors at both the country level and over time (Kölbel et al., 2017; Petersen, 2008). The full models we estimate can be expressed by the following equation, where μ_t and d_t are the time and regional effects and $\varepsilon_{i,t}$ is the stochastic error. For robustness, we also run an alternative panel-corrected standard error models using the xtpcse estimator in STATA.

Table 3
Variables description and data sources.

Variable name	Variable description	Data source
Green	Count of new VC-backed or VC-seeking green (environmental) ventures per region per year.	Crunchbase, BLab and SASB.
Brown	Count of new VC-backed or VC-seeking brown (fossil fuel) ventures per region per year.	Crunchbase and SASB.
Gray	Count of new VC-backed or VC-seeking gray ventures per region per year.	Crunchbase and SASB.
Green Start-Up Investment	Regional start-up investment ($ million).	Crunchbase
Environmental_Knowledge	Fractional green patent count per region per year.	OECD REGPAT, OECD iLibrary.
Environmental Policy Stringency (EPS)	Country level annual indices.	OECD iLibrary – Regional Statistics.
Regional Start-Up Funding	Total equity and debt funding to start-ups per region per year across all types of start-ups. The availability of regional VC financing has been shown to reliable determinant of new entrants across sectors.	Crunchbase.
Regional GDP / capita	Regional GDP / capita. This measure is used to control for the relative level of development and economic activity across regions.	OECD iLibrary – Regional Statistics.
Ren Energy % of Tot. Energy	Renewable energy as percentage of primary energy supply. This control variable measures the progress of the country towards achieving full low carbon energy generation and also proxies a potential level of opportunity or conversely of saturation in the low carbon energy sector.	OECD Statistics.
Renewable Industry Tilt	The ratio between the revenues of listed renewable and the revenues of listed non-renewable energy companies in a given year as a proxy for the dominance of either green or fossil fuel incumbent structures.	SASB and Datastream.
Regional Research Institutes	Number of regional R&D institutions in a given year. Public and private research facilities have been shown to be an important factor in regional innovation and production of new knowledge. In addition, this measure also proxies potential knowledge creation that is not necessarily patentable hence does not appear in our measures of environmental or gray knowledge creation.	GRID (Global Research Identifier Database)

$$\ln(Green\ \ Start-Up\ \ Funding_{i,t}) = \beta_1{*}ln(Environmental\ \ Knowledge_{i,t-1}) + \beta_2{*}ln(EPS_{i,t-1}) + \beta_3{*}ln(GDP\ \ per\ \ Capita_{i,t-1}) + \beta_4{*}ln(Ren\ \ Energy\ \ \%\ \ of\ \ Tot\ \ Energy_{i,t-1}) + \beta_5{*}ln(Renewable\ \ Industry\ \ Tilt_{i,t-1}) + \beta_6{*}ln(Regional\ \ Research\ \ Institutes_{i,t-1}) + \mu_t + \varepsilon_{i,t}$$

4. Descriptive statistics

Overall, the number of new VC-backed gray start-ups across the 24 OECD countries has increased significantly from over 3,800 companies in the year 2001 to a peak of over 14,000 in 2012 and 2013. The same pattern applies for the green start-up sector but not fossil fuel start-ups, whose growth has been modest over the same period (2001 – 2013). Cumulatively, the most prominent green sub-sectors are renewable energy generation with 621 new start-ups, followed by 598 start-ups engaged in environmental data, software, consulting or finance activities, 391 start-ups working on energy efficiency solutions and 306 companies focused on low carbon materials R&D and/or manufacturing. Battery technologies, electric vehicles, biofuels and grid solutions have less than 200 start-ups in each category over our period of analysis (Fig. 1 and 2).

The financing of green start-up sub-sectors however is dependent largely on the capital required to scale innovations, and hence, despite their numbers, start-ups engaged in environmental data, software, consulting or finance activities require modest amounts of capital ($1.7 billion over 2001 -2013, Fig. 2) (Bachher et al., 2014; Gaddy et al., 2017), compared to over $12.6 billion which has gone into renewable energy generation or over $8.8 billion in low carbon materials R&D. The funding of green start-ups the same period has been through early stage funding (over $12.7 billion), late stage funding rounds (just under $13.1 billion), venture debt ($3.6 billion), private equity ($5.3 billion) and grants ($1.4 billion). Funding through venture debt is a sign a maturity in start-ups, as in the absence of cashflows to be able to service debt, the initial phases of start-up development are financed through equity and grants (Fig. 3 and 4).

At the country level, between 2001 – 2013, the US claims over 65% of the total number of new VC-backed green start-ups and gray start-ups and c. 56% of new fossil fuel start-ups across the 24 OECD countries in our dataset. New green start-ups in California represent over 33% of the US total new green cohort, as well as 22% out of the OECD's new green ecosystem. This is a consequence of California's dominance in the technology and entrepreneurship space for a long time and the willingness of many venture capitalists to finance the first movers in the green venture space.

The UK follows with 215 new green start-ups which is just below 9% of the cumulative number of green start-ups across the OECD, with Greater London and South-East England are the first and third regions by number of new green entrepreneurs across the OECD excluding the US. The geography of green entrepreneurship is influenced by the geography of other more established technology clusters as well as by the characteristics in the natural environment, particularly for technologies such as solar, wind and tidal energy generation (Knight, 2012) (Table 4).

The fossil fuel start-up sector is very much clustered around natural resource rich regions and countries where the oil and gas industry has established itself for a long time. Brown start-ups have a complementary business model to that of fossil fuel incumbents, mainly in digital technologies for operation and maintenance of oil and gas operations of which they capture a market of c. USD 24 billion (BNEF, 2017). The regions with the highest number of fossil fuel start-ups over the 2000 – 2013 period are: Texas (US) - 215; Alberta, British Columbia and California with 83,70 and 58 brown start-ups respectively. The geographic distribution of new start-ups is positively correlated with that of new regional funding patterns which are further illustrated in Appendix A.1.

5. Synthesis of results

Environmental knowledge, policy and start-up entry and financing

Models 1a,c,e in Table 5 illustrate how environmental knowledge and our control variables are related to new start-up rates across sectors (green, gray and brown). We find a strong positive relationship between the creation of new environment related knowledge and the emergence of green start-ups ($\beta = 0.193$, $p < 0.01$), and a weaker, but nevertheless significant relationship with gray start-up creation ($\beta = 0.06$, $p < 0.05$), and no significant relationship between environmental knowledge and brown start-up creation. Similarly, models 1b,d,f show that there are significant spillovers from gray knowledge creation into both gray ($\beta = 0.236$, $p < 0.001$) and green entrepreneurship ($\beta = 0.232$, $p < 0.001$). Our models further unveil that the number of regional research institutes in a region, which is also a proxy for new knowledge creation including non-patentable inventions, is positively

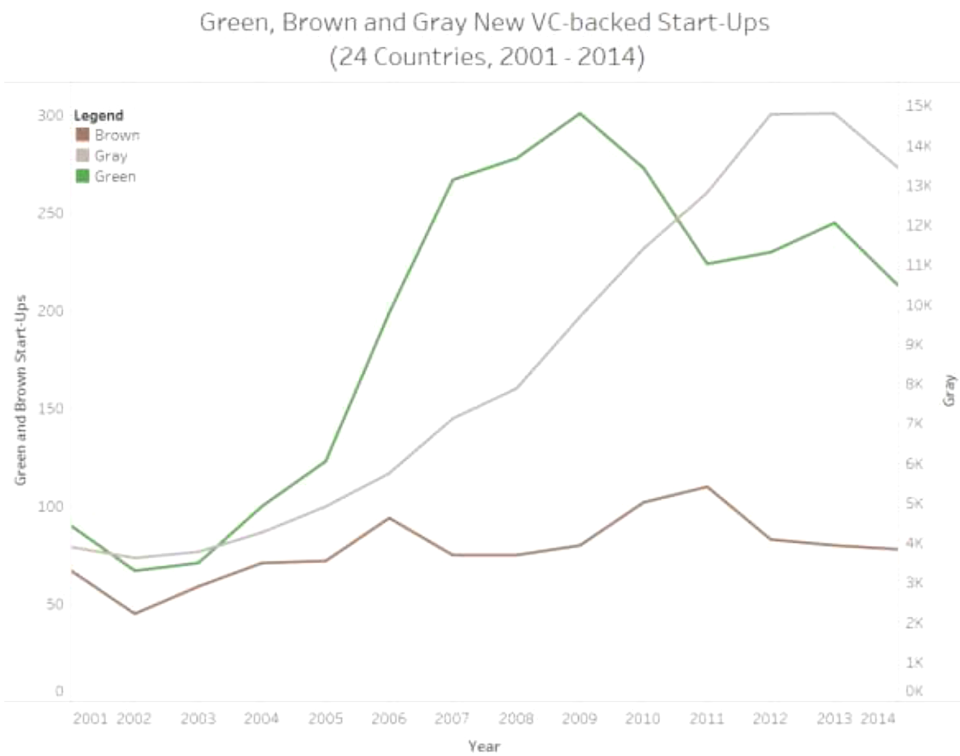

Fig. 1. VC-backed start-up entries across 24 OECD countries between 2001 - 2014. Source: authors based on data from Crunchbase.

and significantly related to the emergency of gray, green and brown ventures across the board (models 1a-f).

Table 5 also offers preliminary insights with respect to the impact of environmental policy on start-up entry. We find that the aggregate environmental policy stringency measure is not statistically related to the emergence of new green ventures, but negatively related with the emergence of both gray (β = -0.327, $p < 0.001$, model 1a) and brown ventures (β = -0.792, $p < 0.01$, model 1e).

Models 2a-c (Table 6) illustrate that new environmental knowledge production in a region is still beneficial for the financing of gray start-ups (β = 0.057, $p < 0.05$, model 2a), but statistically insignificant for either green or brown start-ups. Surprisingly, the aggregate environmental policy stringency index is positively related to gray (β = 1.153, $p < 0.001$), green (β = 0.991, $p < 0.001$) and brown venture financing (β = 0.312, $p < 0.05$).

Granular environmental policy instruments and start-up entry and financing

Next, we provide more granular evidence on the relationship between different types of environmental policy instruments and gray, green and brown entrepreneurship entry (Table 7, models 3a-l). Model 3a shows that the entry of new gray ventures is negatively related to the generosity of feed-in-tariffs (β = - 0.084, $p < 0.05$). On the other hand,

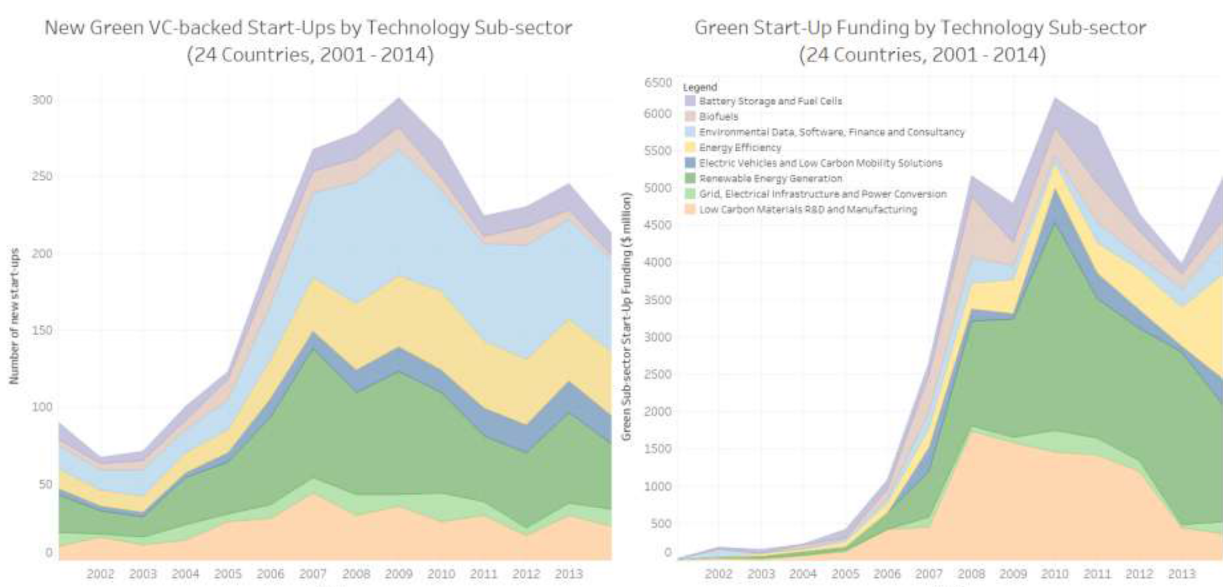

Fig. 2. Number of new green start-ups and start-up funding amount by green technology sub-sector in $ million between 2001 -2014. Source: authors based on data from Crunchbase.

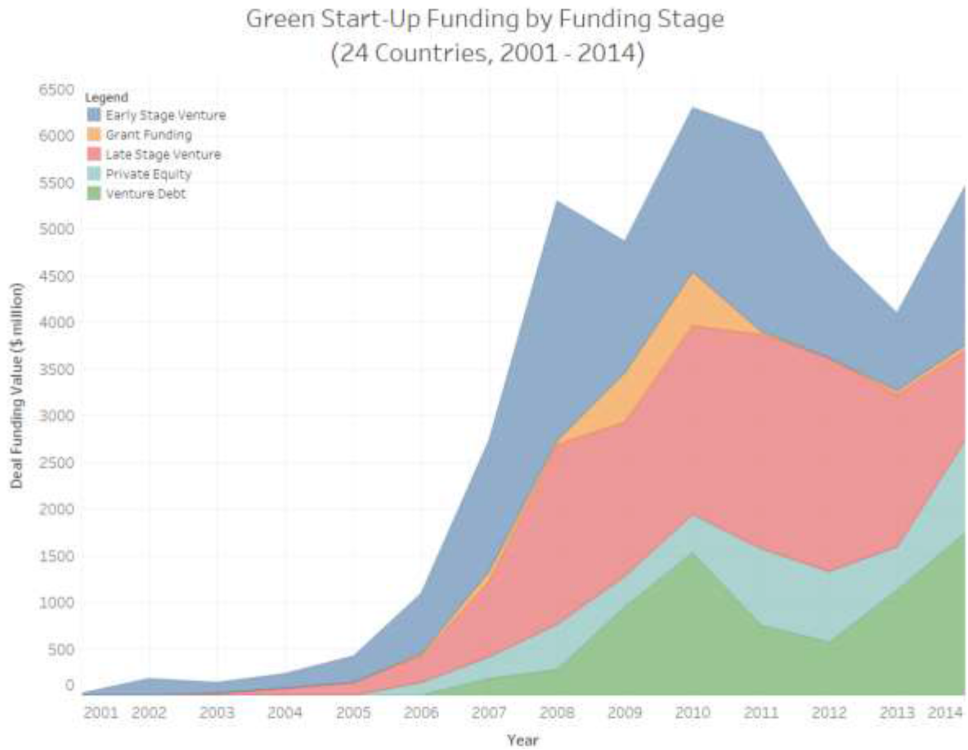

Fig. 3. Start-up funding amount by green technology funding stage in $ million between 2001 -2014. Source: authors based on data from Crunchbase.

green entrepreneurship entry seems to be negatively impacted by the relative generosity of R&D subsidies (β = - 0.267, p < 0.1, model 3b). This is also the case for battery technology, renewable energy generation and low carbon materials start-ups, but not across the other 5 green sub-sectors. Model 3c shows a negative and significant relationship between new brown ventures and environmental taxes (β = -0.945, p < 0.001), stringency of trading schemes (β = -0.420, p < 0.01) as well as that of feed-in-tariffs (β = -0.186, p < 0.1).

As far as other policy instruments are concerned, we find a positive and significant relationship between emission standards and new battery start-up emergence (β = 1.061, p < 0.05, model 3d). Trading schemes are also positively and significantly related to the emergence of energy efficiency and grid-related technology start-ups, but unrelated to any other types of green start-up emergence.

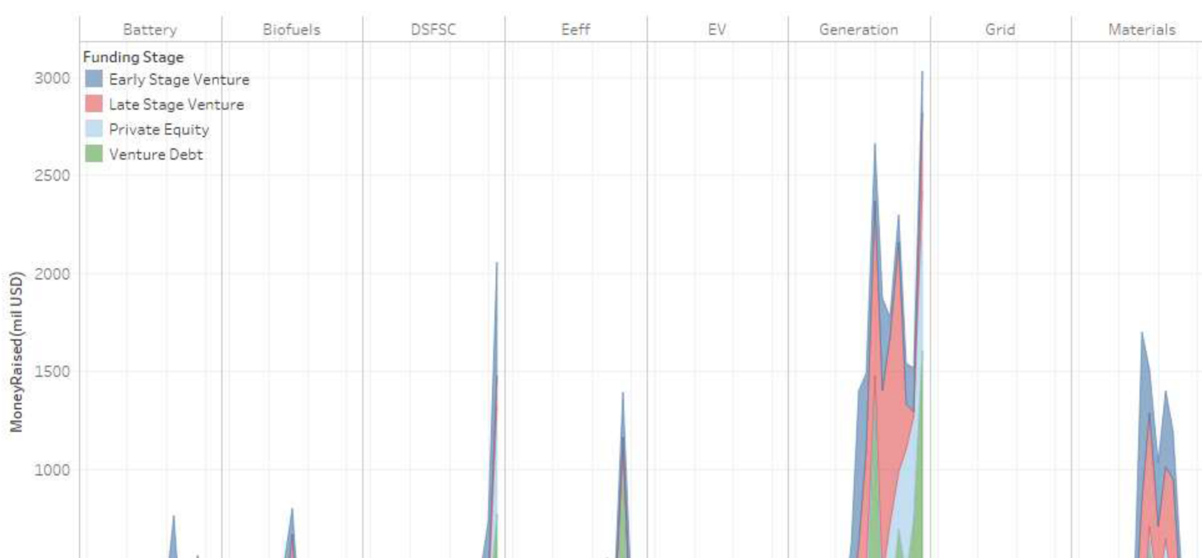

Fig. 4. Start-up funding amount by green technology funding stage and sub-sector in $ million between 2001 -2014. Source: authors based on data from Crunchbase.

Table 4
Country and regional cumulative VC-backed or VC-seeking start-up entry between 2001 and 2013. For US states distribution we display only states with more than 14 green start-ups cumulatively. For OECD regional (excluding US) statistics we display only regions with more than 10 cumulative green start-ups. Tables are sorted descending by total number of green start-ups.

Country	Gray	Green	Brown	US Region	Gray	Green	Brown	Non-US Region	Gray	Green	Brown
United States	69,272	1,626	572	**California**	21,725	551	58	**Greater London**	5,434	70	28
United Kingdom	10,115	215	90	**Massachusetts**	3,447	138	6	**Ontario**	2,423	61	32
Canada	4,792	129	208	**Texas**	3,761	106	215	**South East England**	1,258	42	16
Germany	2,954	74	11	**New York**	8,278	102	36	**Southern and Eastern**	1,356	39	8
Australia	2,403	59	42	**Colorado**	1,914	58	41	**British Columbia**	1,088	33	70
France	2,605	58	17	**Washington**	2,337	53	6	**West-Nederland**	1,161	32	5
Spain	2,885	56	6	**Illinois**	2,917	53	6	**Île-de-France**	1,738	31	11
Netherlands	1,477	49	8	**Florida**	3,144	41	13	**New South Wales**	1,097	23	7
Ireland	1,483	40	11	**Pennsylvania**	1,715	39	18	**East of England**	588	20	8
Sweden	1,011	37	8	**North Carolina**	1,180	33	4	**Bavaria**	620	20	1
Italy	896	24	1	**Oregon**	832	32	4	**Stockholm**	596	19	4
Denmark	639	23	1	**Georgia**	1,589	30	5	**Scotland**	419	19	18
Finland	652	17	0	**Michigan**	852	24	6	**Madrid**	929	18	3
Belgium	522	16	3	**Maryland**	963	24	5	**Victoria**	709	17	10
Mexico	350	10	1	**Arizona**	1,028	24	8	**Quebec**	695	14	13
Austria	382	10	0	**Ohio**	1,111	23	11	**Catalonia**	881	14	1
Norway	299	7	27	**Virginia**	1,394	22	2	**Berlin**	937	14	3
Japan	701	6	2	**New Jersey**	1,414	22	7	**Yorkshire and The Humber**	311	13	5
Portugal	124	3	1	**District of Columbia**	689	22	2	**South West England**	430	13	2
Poland	522	3	0	**Connecticut**	639	19	3	**North West England**	627	13	6
Hungary	130	2	0	**Nevada**	653	17	9	**Helsinki-Uusimaa**	486	13	0
Greece	171	2	3	**Minnesota**	754	17	6	**Capital (DK)**	452	12	1
Slovak Republic	70	1	1	**Tennessee**	798	16	9	**Zuid-Nederland**	152	11	1
Czech Republic	230	1	0	**Utah**	844	15	5	**Flemish Region (Vlaams Gewest)**	296	11	2

Across all but two green sub-sectors (biofuels and grid technologies), we find evidence that new environmental knowledge creation is conducive to new green start-up entries. Biofuels and grid technology start-ups on the other hand are heavily influenced by the existing infrastructure and seem to not rely on the local knowledge pool related to the environment.

Granular environmental policy instruments and start-up financing

In Table 8, we expand on our analysis above to explore the effect of new environmental knowledge creation on green sub-sector financing. We find that new environmental knowledge creation has no effect on the start-up financing of six out of the eight green sub-sectors, except for biofuels and energy efficiency start-ups, for which the effect is both positive and significant (models 4d-l).

We further show that green start-up financing is negatively related to the stringency of environmental taxes (β = -0.326, $p < 0.05$, Table 8), positively and significantly related to the generosity of feed-in-tariffs ($\beta = 0.202$, $p < 0.001$) as well as to the stringency of emission standards regulations ($\beta = 0.585$, $p < 0.001$). These effects are also applicable to the overall grey sector, they persist at the green subsectoral level for the majority of sub-technologies and also hold when we analyse the effect of environmental policy across different funding stages rather than overall funding (models 5a-d, Table 9). At the green sub-sector level, trading schemes are negatively and significantly related to green start-up investment within the biofuels, EV and generation sub-sectors, whereas R&D subsidies do not seem to be related with

Table 5
Control variables, new knowledge stocks models and aggregate environmental policy stringency effects on gray, green and brown new regional venture creation.

New regional venture creation	Gray		Green		Brown	
Model	**1a**	**1b**	**1c**	**1d**	**1e**	**1f**
Environmental Knowledge	0.060*		0.193**		0.038	
	(0.023)		(0.059)		(0.073)	
Gray Knowledge		0.236***		0.252***		0.010
		(0.042)		(0.062)		(0.083)
Environmental Policy Stringency	-0.327***	-0.286**	-0.153	-0.207	-0.792**	-0.801**
	(0.096)	(0.093)	(0.246)	(0.249)	(0.289)	(0.288)
GDP per Capita	0.721***	0.556**	1.378***	1.277***	1.329***	1.348***
	(0.189)	(0.186)	(0.279)	(0.260)	(0.327)	(0.327)
Start-up Funding	0.027**	0.029***	0.177***	0.169***	0.135**	0.136**
	(0.008)	(0.008)	(0.034)	(0.035)	(0.042)	(0.042)
Ren Energy % of Tot. Energy	-0.120	-0.100	-0.184+	-0.154	-0.146	-0.145
	(0.080)	(0.079)	(0.105)	(0.106)	(0.166)	(0.166)
Renewable Industry Tilt	0.025	0.026	-0.089*	-0.094*	-0.115	-0.111
	(0.030)	(0.032)	(0.039)	(0.039)	(0.095)	(0.095)
Research Institutes	0.877***	0.689***	0.501***	0.435***	0.809***	0.830***
	(0.083)	(0.089)	(0.094)	(0.092)	(0.125)	(0.141)
AIC	16454.44	16402.66	4341.115	4330.43	2615.824	2616.028
Num. obs.	3809	3809	3809	3809	3809	3809
Num. groups: Regions.	293	293	293	293	293	293

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, +$p < 0.1$. New venture creation random effects negative binomial model. Dependent variable is the count of new regional VC-backed or VC-seeking start-ups. Dataset is a balanced regional panel over 2001 – 2013. Independent variables are lagged 1 year. Cluster (region) robust standard errors in parentheses.

Table 6
Control variables, new knowledge stock models and environmental policy stringency effect on gray, green and brown regional venture financing.

New regional venture financing	Gray	Green	Brown
Model	**2a**	**2b**	**2c**
Environmental Knowledge	0.057*	0.006	-0.003
	(0.025)	(0.025)	(0.016)
Environmental Policy Stringency	1.153***	0.991***	0.312*
	(0.223)	(0.194)	(0.152)
GDP per Capita	-1.119***	-1.283***	-0.158*
	(0.325)	(0.296)	(0.073)
Ren Energy % of Tot. Energy	0.234	0.155	-0.010
	(0.159)	(0.135)	(0.058)
Renewable Industry Tilt	0.140**	-0.005	-0.005
	(0.048)	(0.033)	(0.009)
Research Institutes	0.066	-0.425	-0.063
	(0.357)	(0.266)	(0.069)
Num. obs.	3809	3809	3809
Adj. R^2	0.835	0.547	0.326
Num. groups: Regions.	293	293	293

***p < 0.001, **p < 0.01, *p < 0.05, +p < 0.1. New start-up financing log-normal OLS models. Dependent variable is the natural logarithm of the total regional green start-up funding in a given year in $ million, including across green sub-sectors. Dataset is a balanced regional panel over 2001 – 2013. Independent variables are lagged 1 year. Two-way cluster (region and time) robust standard errors in parentheses.

financing in any particular sector. However, in our analysis of environmental policy effects on types of venture funding (Table 9), we find a positive and significant relationship between the generosity of R&D subsidies and green start-up financing through venture debt.

6. Discussion

Our findings provide several contributions to the rising field of green entrepreneurship, which we explain by drawing from the literatures on knowledge spillovers and institutional theory. Our first focus has been to test the KSTE in the context of green, gray and brown entrepreneurship. Our results confirm the underlying assumption of the KSTE that new environmental knowledge can be conducive to new green venture creation, and does so over 293 countries and 24 countries, which significantly expands the geographical scope of previous studies (Audretsch and Lehmann, 2005; Colombelli and Quatraro, 2017; Vedula et al., 2018). What was previously unanswered in the literature so far was whether it is possible that both brown and gray start-up entry and financing may be influenced by the creation of new regional environmental knowledge. Our results show that this is the case only for gray start-up and confirm the hypothesis of Isaak (2016) that gray start-ups may take advantage of environmental knowledge without explicitly having an environmental goal for their venture. This is complementary to the work of Colombelli and Quatraro (2017) who look at the spillover potential of brown technologies into green entrepreneurship as well as complementary to the patent citation analysis of Dechezleprêtre, Martin and Mohnen (2013) on green and brown technology spillovers. We also highlight the importance of the existing infrastructure, as new entry across all sectors is facilitated by the presence of an increased number of regional research institutes. Regional research institutes represent knowledge sources which in addition to patentable knowledge, produce significant non-patentable knowledge and often act as active knowledge disseminators. Research institutes themselves produce significant non-patentable green knowledge, hence, our model does control to a certain extent to other types of green knowledge than that which is quantified through patent data. Interestingly, the entry of biofuels and grid technology start-ups is highly dependent on the existing infrastructure and not on new environmental knowledge creation, which is not necessarily an exception to the applicability of KSTE, but rather highlights the importance of different types of knowledge bases that lead to an enhanced regional entrepreneurship sector.

Our study highlights the decreasing importance of new regional environmental knowledge creation for green ventures as we move from the study of entrepreneurial entry to the dynamics of start-up financing. This underscores the characteristic of knowledge spillovers as a dynamic process (Feldman and Kelley, 2006), which is more salient at the early stages of green start-ups and fades away as the start-up scales and the uncertainty associated with finding a viable business model and defining the core knowledge and capabilities of the firm decrease (Alvarez and Barney, 2005). Our in-depth investigation allows us to

Table 7
Environmental policy stringency and new brown and green venture creation.

New regional venture creation	Gray	Green	Brown	Battery	Biofuels	DSFSC	Eeff	EV	Generation	Grid	Materials	Green (ZINB Model)
Model	**3a**	**3b**	**3c**	**3d**	**3e**	**3f**	**3g**	**3h**	**3i**	**3j**	**3k**	**3l**
Taxes	0.111	0.060	-0.945***	0.030	0.112	0.023	0.049	-0.897	-0.418	-0.456	-0.292	-0.237
	(0.073)	(0.197)	(0.199)	(0.574)	(0.651)	(0.344)	(0.350)	(0.546)	(0.267)	(0.529)	(0.354)	(0.214)
Trading Schemes	-0.037	0.122	-0.420**	-0.196	0.324	-0.098	0.661**	-0.369	0.272	0.521+	-0.071	-0.127
	(0.038)	(0.117)	(0.154)	(0.380)	(0.309)	(0.235)	(0.224)	(0.293)	(0.173)	(0.314)	(0.223)	(0.155)
FIT	-0.084*	-0.070	-0.186+	-0.156	0.118	-0.052	-0.114	0.042	-0.093	-0.239	0.087	-0.098
	(0.035)	(0.064)	(0.104)	(0.209)	(0.224)	(0.123)	(0.128)	(0.188)	(0.110)	(0.192)	(0.163)	(0.088)
Standards	-0.019	0.173	0.158	1.061*	-0.386	0.417	0.506	-0.782	0.111	0.205	0.200	0.128
	(0.058)	(0.173)	(0.189)	(0.427)	(0.504)	(0.373)	(0.463)	(0.587)	(0.262)	(0.421)	(0.311)	(0.220)
R&D Subsidies	-0.066	-0.267+	-0.151	-0.853**	-0.535	0.034	-0.029	-0.232	-0.452+	0.270	-1.110***	-0.367+
	(0.048)	(0.152)	(0.191)	(0.315)	(0.392)	(0.274)	(0.283)	(0.468)	(0.260)	(0.457)	(0.294)	(0.213)
Environmental Knowledge	0.058*	0.257***	0.039	0.253*	0.198	0.203*	0.308**	0.235*	0.252***	0.004	0.316***	0.156*
	(0.023)	(0.066)	(0.072)	(0.109)	(0.130)	(0.080)	(0.099)	(0.111)	(0.075)	(0.138)	(0.093)	(0.078)
Research Institutes	0.875***	0.644***	0.989***	1.092***	0.762***	0.685***	0.671***	0.817***	0.523***	1.077***	0.711***	0.624***
	(0.084)	(0.107)	(0.145)	(0.189)	(0.166)	(0.151)	(0.180)	(0.183)	(0.099)	(0.166)	(0.120)	(0.164)
Control Variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
AIC	16469.77	4373.153	2600.704	835.0136	802.6469	1975.543	1581.668	848.932	2243.883	757.829	1302.185	4665.215
Log Likelihood	-8208.883	-2160.577	-1274.352	-392.5068	-375.3235	-961.7717	-764.8342	-398.466	-1095.941	-352.91	-625.09	-2304.608
Num. obs.	3809	3809	3809	3809	3809	3809	3809	3809	3809	3809	3809	3809
Num. groups: Regions.	293	293	293	293	293	293	293	293	293	293	293	293

***p < 0.001, **p < 0.01, *p < 0.05, +p < 0.1. New venture creation random effects negative binomial model. Dependent variable is the count of new regional brown and green VC-backed or VC-seeking start-ups, including green sub-sectors. Dataset is a balanced regional panel over 2001 – 2013. Independent variables are lagged 1 year. Cluster (region) robust standard errors in parentheses. Within the set of control variables, we orthogonalize the start-up funding independent variable with respect to GDP per capita to avoid multicollinearity issues.

Table 8
Aggregate gray, green, brown and sub-sector green regional start-up financing.

Regional start-up funding Model	Gray 4a	Green 4b	Brown 4c	Battery 4d	Biofuels 4e	DSFSC 4f	Eeff 4g	EV 4h	Generation 4i	Grid 4k	Materials 4l
Taxes	-0.431*	-0.326*	-0.109	-0.068	-0.018	-0.164*	-0.132+	-0.071	-0.159	-0.110*	-0.149+
	(0.202)	(0.164)	(0.077)	(0.067)	(0.072)	(0.072)	(0.079)	(0.058)	(0.106)	(0.055)	(0.090)
Trading Schemes	0.191	-0.103	0.078	0.004	-0.050+	-0.014	-0.029	-0.032*	-0.076+	-0.014	-0.030
	(0.130)	(0.108)	(0.072)	(0.025)	(0.026)	(0.029)	(0.034)	(0.016)	(0.041)	(0.016)	(0.040)
FIT	0.197***	0.202***	0.064	0.030	0.053***	0.047*	0.030	0.013	0.101***	0.026**	0.073***
	(0.060)	(0.061)	(0.056)	(0.022)	(0.015)	(0.024)	(0.019)	(0.009)	(0.030)	(0.008)	(0.022)
Standards	0.613***	0.585***	0.125*	0.082+	0.158*	0.120**	0.147*	0.144*	0.299***	0.099**	0.260***
	(0.130)	(0.135)	(0.062)	(0.042)	(0.063)	(0.045)	(0.062)	(0.059)	(0.088)	(0.038)	(0.079)
R&D Subsidies	0.101	0.081	0.013	0.052	-0.033	-0.013	-0.003	0.038	0.070	0.018	0.053
	(0.152)	(0.139)	(0.026)	(0.039)	(0.031)	(0.031)	(0.054)	(0.028)	(0.053)	(0.028)	(0.066)
Environmental Knowledge	0.068**	0.022	-0.001	0.003	0.026+	0.006	0.023*	0.000	0.013	0.003	0.006
	(0.025)	(0.023)	(0.015)	(0.007)	(0.015)	(0.010)	(0.011)	(0.009)	(0.015)	(0.006)	(0.012)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Num. obs.	3809	3809	3809	3809	3809	3809	3809	3809	3809	3809	3809
Adj. R^2	0.837	0.556	0.328	0.480	0.374	0.337	0.519	0.307	0.390	0.297	0.472

***p < 0.001, **p < 0.01, *p < 0.05, +p < 0.1. New start-up financing log-normal OLS models. Dependent variable is the natural logarithm of the total regional green start-up funding in a given year in $ million, including across green sub-sectors. Dataset is a balanced regional panel over 2001 – 2013. Independent variables are lagged 1 year. Two-way cluster (region and time) robust standard errors in parentheses

Table 9
Aggregate regional green start-up financing by deal stage.

Regional green start-up funding Model	VC Early Stage 5a	VC Late Stage 5b	Private Equity 5c	Venture Debt 5d
Taxes	-0.229+	-0.237*	-0.051	-0.255+
	(0.123)	(0.110)	(0.098)	(0.130)
Trading Schemes	-0.079	-0.052	-0.019	0.005
	(0.085)	(0.042)	(0.027)	(0.025)
FIT	0.142**	0.058*	0.060+	0.057***
	(0.049)	(0.027)	(0.031)	(0.016)
Standards	0.428***	0.286***	0.114*	0.220**
	(0.118)	(0.082)	(0.050)	(0.080)
R&D Subsidies	0.098	0.017	-0.021	0.081+
	(0.108)	(0.060)	(0.036)	(0.045)
Environmental Knowledge	0.015	0.020	-0.002	0.014
	(0.022)	(0.014)	(0.007)	(0.009)
Control Variables	YES	YES	YES	YES
Num. obs.	3809	3809	3809	3809
Adj. R^2	0.541	0.378	0.131	0.275

***p < 0.001, **p < 0.01, *p < 0.05, +p < 0.1. New start-up financing log-normal OLS models. Dependent variable is the natural logarithm of the total regional green start-up funding across different start-up funding stages in a given year (in $ million). Dataset is a balanced regional panel over 2001 – 2013. Independent variables are lagged 1 year. Two-way cluster (region and time) robust standard errors in parentheses.

find exceptions to the application of theory, such as it is the case with the biofuels technology sub-sector. While new regional environmental knowledge does not influence biofuels start-up entry, we find that it plays a significant role in their financing. This may be due to the fact that biofuels have a downstream value chain which is closely aligned to that of the mainstream oil and gas sector, hence the core knowledge is closely linked to the existing infrastructure, but may require specific environmental knowledge and regional support in the scale-up and financing process.

The second major focus of our study has been to unveil the relationship between environmental policy and brown start-up entry as well as green start-up entry and financing outcomes (see Table 10 for summary of findings). To our knowledge, this is one of the first studies to show that more stringent environmental policy has negatively impacted new entries in the fossil fuel sector, particularly due to policies such as environmental taxes and trading schemes which penalise heavy emitting and polluting industries. We interpret these findings in the light of institutional theory (Bruton et al., 2010), as governments seek to de-legitimise as well as to directly discourage fossil fuel intensive activities through their policy design (David, 2017; Hepburn, 2010). However, we find that once fossil fuel ventures are founded, they benefit from a more stringent emissions standards regime through enhanced regional funding access, which suggests that there are still opportunities for new brown ventures which may help fossil fuel incumbents become more emissions efficient.

We also find support for the assertion of institutional theorists that regulation is likely to matter less for new green venture entry, as green entrepreneurs have been shown to rely on social movements and normative informal institutions at the early stages of the their development (Sine and Lee, 2009; Vedula et al., 2018; York and Lenox, 2014).

We do find however a counterintuitive exception, in that the generosity of green R&D subsidies is negatively related to new green start-up entry, particularly in the case of battery technologies, renewable energy generation and materials R&D. While government R&D subsidies have the potential to generate significant knowledge spillovers (Feldman and Kelley, 2006), there may also be a potential for R&D subsidies to discourage risky start-up ventures. In this respect, Feldman and Kelley (2006, p. 1517) note that there may be a "bias the selection of projects towards those with the greatest chances of commercial success rather than those riskier projects that may generate the highest social rates of return." Given the capital intensiveness of the battery, generation and materials subsectors (Gaddy et al., 2017), it may be that entrepreneurs expect that R&D subsidies are awarded specifically for firms that have little or no track record. From the construction of the OECD policy stringency index, it is not possible to investigate whether green R&D subsidies are targeted at larger companies and incumbent structures vs. newly established start-ups, however we are able to test which type of follow-on funding a more generous green R&D subsidy regime encourages (Table 9). Our finding that R&D subsidies encourage follow-on funding of venture debt suggests that R&D is indeed targeted at already proven and scalable businesses that have reasonable cashflows to service their debt.

Our insights related to the impact of environmental policies on green start-up financing provide further validation to the literature on institutional theory and venture capital (Li and Zahra, 2012). The most prominent (positive) influence on new green venture financing is due to the generosity of feed-in-tariffs and emission standards. This is in line with the findings of previous studies, which are focused on renewable energy generation, and in particular solar generation (Criscuolo and Menon, 2015; Georgallis et al., 2018; Georgallis and Durand, 2017). We show that the impact of these policies has been catalytic across a wide range of green start-ups, beyond renewable energy generation. For

Table 10
Results summary across green start-up entry and financing models.

	Gray		Brown		Green		Battery		Biofuels		DSFSC		Eeff		EV		Generation		Grid		Materials	
	Entry	Fin	Entry	Fin	Entry	Fin	Entry	Fin	Entry	Fin	Entry	Fin	Entry	Fin	Entry	Fin	Entry	Fin	Entry	Fin	Entry	Fin
Taxes		-*	-***			-*						-*		-*						-*		-*
Trading Schemes			-**							-ˆ			+**			-*		-*	+ˆ			
FIT	-*	+***	-ˆ			+***				+***		+*						+***		+**		+***
Standards		+***		+*		+***	+*	+*		+*		+**		+*		+*		+***		+**		+***
R&D Subsidies					-ˆ		-**										-ˆ				-***	
Environmental Knowledge	+*	+**			+***					+*				+*								

***p < 0.001, **p < 0.01, *p < 0.05, +p < 0.1.

select subsectors, our finding that environmental taxes discourage green start-up financing confirm the study of Hörisch et al. (2017) as well as the fact that taxes may be perceived as an inflexible way to deal with the regulation of environmental externalities (Hepburn, 2010).

Feed-in-tariffs have been perceived in the literature as having more elements of industrial policy rather than environmental policy (Georgallis et al., 2018), as governments stated that the major reason for their introduction is to foster local investment (Georgallis and Durand, 2017). Our findings confirm that these policies have had a significant impact in attracting investment for renewable energy generation and closely related technologies in the generation value chain (including grid, biofuels, materials) and service-oriented start-ups in the green sector (i.e. consultancy, parts suppliers etc.).

Emission standards emerge as the most reliable policy in fostering green start-up investment across all sub-sectors and investment stages. The literature acknowledges that standards may be more useful in dealing with externalities in highly dispersed sectors where the costs of environmental monitoring is too high (Botta and Koźluk, 2014). This suggest that the deployment of emissions standards is associated with a dispersed incumbent structure, whose coordination may be much slower in responding to disruption from green start-ups.

7. Implications and conclusions

Overall, our study yields important implications for both theory and practice. While KSTE has proven to be a useful framework in the context of start-up entry, it is less known what role knowledge spillovers play post entry, and how new knowledge shapes the financing and subsequent growth of new entrants. Our findings show that environmental knowledge significantly affects entry in but not the financing of green sub-sectors. We also highlight the exception (the biofuels sector), where the dynamics are reversed, which provides a significant opportunity for innovation and entrepreneurship scholars to further investigate the dynamic mechanisms through which the importance of new regional knowledge rises or fades throughout the start-up development process.

Our study contributes to institutional theory by both confirming the findings of previous studies (Sine and Lee, 2009; York and Lenox, 2014) that entrepreneurs tend to draw on local knowledge and informal institutions in their decision to enter a sector and that formal regulation does not influence entrepreneurship decision making at this stage. However, we also provide evidence contradicting this theory, showing that for select green capital-intensive sub-sectors (battery technologies, renewable energy generation and low carbon materials), entrepreneurs do pay attention to the R&D subsidy regime and start-up funding support from governments. The institutional theory and entrepreneurship literature would hence benefit from further research into the context and conditions under which the regulatory pillar of Scott (1995) plays an important role in the entry, financing and scale-up of new entrants.

The implication for effective policy design is that while environmental stringency of policies may be a necessary condition for the transition to a low carbon economy, it is not always sufficient in motivating new venture entry, although it appears to have been successful in catalysing green start-up investment. These policies should also be adjusted to suit a national or regional entrepreneurship ecosystem if the policymaker view is that entrepreneurs are important in delivering the low carbon transition. While R&D subsidies have the potential to significantly improve knowledge spillovers (Feldman and Kelley, 2006), and subsequently encourage new entrants (Acs et al., 2009; Audretsch and Keilbach, 2007), policymakers should also consider their immediate impact on potential new entrants as R&D subsidies may favour incumbent structures and businesses with an established track record (Feldman and Kelley, 2006). Our findings further enhance the understanding of policymakers with respect to the limitations of entrepreneurs in trying to “green” the incumbent fossil fuel sector, as the geographical distribution of brown start-up emergence is unrelated to new regional environmental knowledge creation.

The lessons for entrepreneurs are also manifold. First, aspiring green entrepreneurs may enhance their likelihood of founding promising start-ups by participating in knowledge networks that have deep expertise in environmental management. Entrepreneurs who may not have environmental goals at all can also benefit by understanding the benefits of effective environmental management on their business models. Finally, entrepreneurs may enhance their opportunities by participating in what Dean and McMullen (2007) call political entrepreneurship, or in other words, taking action in altering the nature of government policies. These policies need not be more environmentally stringent, but perhaps better matched with the country's or region's entrepreneurship policy.

Our study has some limitations. While we manage to provide evidence at the granular policy instrument level, and how it affects new rates of entrepreneurship, we are unable to distinguish between the relative coherence, credibility or comprehensiveness of the policy instruments at the country level which ultimately influence the environmental and economic outcomes of the policy (Georgallis et al., 2018; Rogge and Reichardt, 2016). Furthermore, policy instruments interact with each other and may enhance or diminish the overall strength of a policy regime. Further research would need to be conducted to explore these aspects. Another limitation has to do with the dataset which allows us to study environmental knowledge and policy effects on entry and financing of VC-backed or VC seeking start-ups only. Seeking to answer questions, such as does environmental policy affect the revenue growth of start-ups or do start-ups meaningfully contribute to the reduction of environmental degradation can provide complementary views to our research angle. To alleviate potential concerns for reverse causality, all independent variables are lagged one year. It is possible however that as the green start-up pool receives more funding, it will generate more green related knowledge which in turn influences green entrepreneurship. However, in this case, the start-up producing green knowledge may be considered itself an incumbent or competitor for the next generation of green start-ups, so to that extent, that may ease some endogeneity concerns. Additional bias may be introduced in our study since we were able to only consider green patents published in English only. The research institutes control variable partly addresses this issue for non-patentable green knowledge production, but not entirely. Our measure of green venture entry and financing, while uses a robust dataset (which compares in coverage to other research providers such as Preqin), relies on self-disclosed data from companies and venture capitalists which is prone to bias. As much as possible, this has been complemented with additional datasets (e.g Blab data) to ensure a representative sample of green, gray and brown VC-backed start-up ventures across our 293 regions and 24 countries.

Declaration of Competing Interests

The authors declare that they have no conflicts of interest.

CRediT authorship contribution statement

Theodor F. Cojoianu: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing - original draft, Writing - review & editing, Visualization. **Gordon L. Clark:** Conceptualization, Methodology, Supervision, Funding acquisition, Writing - review & editing, Resources. **Andreas G.F. Hoepner:** Conceptualization, Methodology, Investigation, Formal analysis, Writing - review & editing, Funding acquisition. **Paolo Veneri:** Conceptualization, Methodology, Data curation, Writing - review & editing, Resources. **Dariusz Wójcik:** Conceptualization, Methodology, Writing - review & editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

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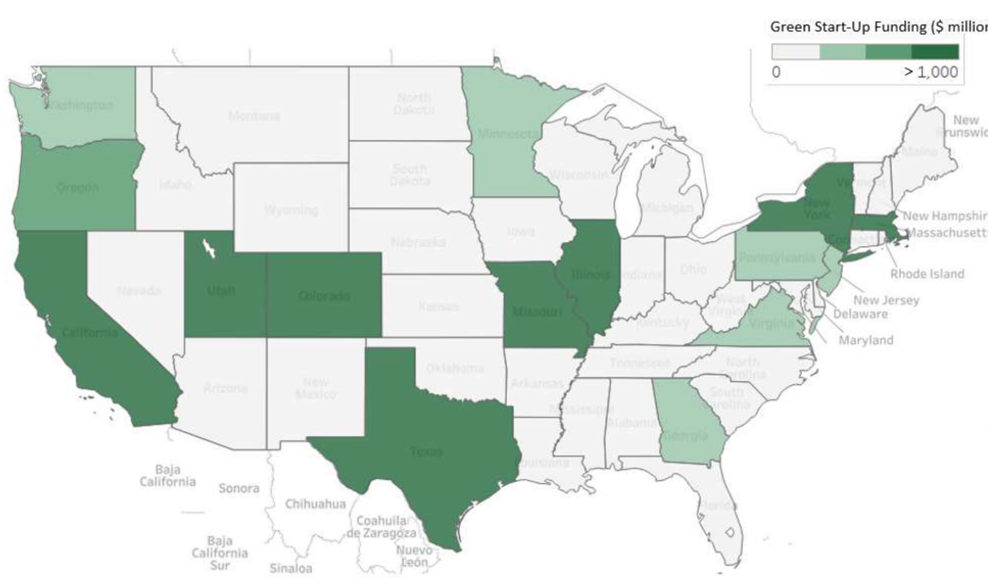
Supplementary materials

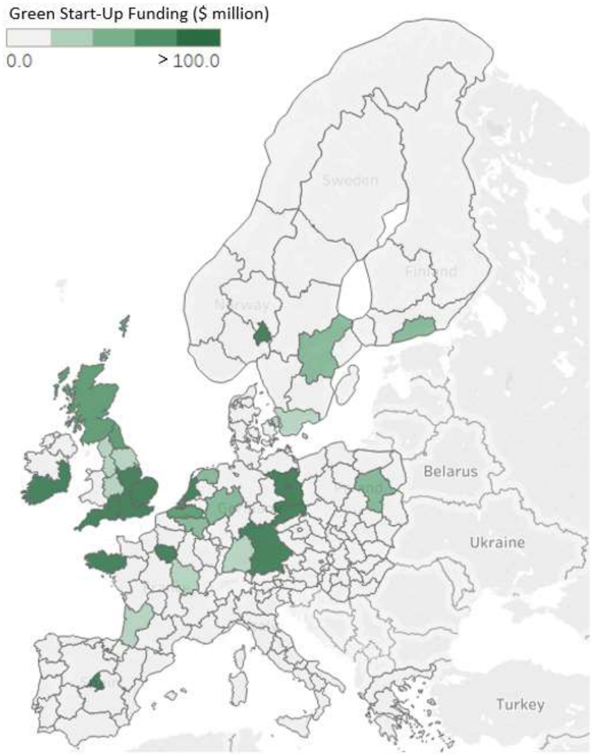
Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.respol.2020.103988.

Appendices Appendix. A.1. US and European distribution of green start-up funding (2001 -2014)



Region / State	Fundraised Amount ($ million)
California	16,406
Massachusetts	5,093
Texas	2,069
Colorado	1,718
New York	1,549
Illinois	1,383
Utah	1,005
Missouri	781
Oregon	672
Pennsylvania	450
Virginia	450
Georgia	418
Minnesota	400
Washington	339
New Jersey	275
Nebraska	237
North Carolina	226
New Hampshire	221
Vermont	206

Appendix A.1. - continued



Region	Fundraised Amount ($ million)
Greater London	328
Oslo and Akershus	324.9
Southern and Eastern	324.7
Madrid	198.4
South East England	180.3
East Midlands	177.6
East of England	176.9
Bavaria	175.8
Berlin	171.4
West-Nederland	149.7
Île-de-France	137.3
Brittany	130.7
Saxony	115.5
South West England	109.2
Brandenburg	90
North East England	67.8
Flemish Region (Vlaams Gewest)	64.9
Scotland	60.4
Helsinki-Uusimaa	58.2
North Rhine-Westphalia	55.6
Mazowieckie	55.4
Wallonia (Région wallonne)	52.8
East Middle Sweden	51.6
Noord-Nederland	47
North West England	36.4
South Sweden	35.7
Burgundy	30.8
Capital (DK)	27.4
Aquitaine	26.6
Yorkshire and The Humber	24.5
Baden-Württemberg	22.9
West Midlands	20.6

Appendix A.2. Correlation Matrix and Descriptive Statistics

Variables	N	Min	Max	Mean	Sd
[1] Green Start-ups	3809	0	73	0.65	3.09
[2] Gray Start-Ups	3809	0	3325	27.48	129.75
[3] Brown Start-Ups	3809	0	27	0.27	1.29
[4] Environmental Knowledge	3809	0	5209.2	78.85	280.31
[5] Start-Up Funding ($million)	3809	0	22353.52	81.58	719.59
[6] Environmental Taxes	3809	0	4	1.6	0.75
[7] Emissions Trading Schemes	3809	0	5.2	1.11	1.22
[8] Feed-in-tariffs (FIT)	3809	0	6	1.72	1.95
[9] Emissions Standards	3809	0.75	6	3.36	1.48
[10] Green R&D Subsidies	3809	0	6	2.06	1.15
[11] Regional GDP per Capita ($/capita)	3809	5844	171586	33862.56	15948.5
[12] Ren. Energy % Total Energy Supply	3809	1.02	51.55	9.51	8.34
[13] Research Institutes	3809	0	2332	128.64	221.23
[14] Renewable Energy Tilt	3809	0	283.43	7.58	39.61
[15] Green VC ($ million)	3809	0	3380.69	9.27	102.8

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
[1] Green Start-ups														
[2] Gray Start-Ups	0.859***													
[3] Brown Start-Ups	0.371***	0.393***												
[4] Environmental Knowledge	0.287***	0.317***	0.131***											
[5] Start-Up Funding	0.817***	0.897***	0.291***	0.292***										
[6] Environmental Taxes	-0.02	-0.0432**	-0.02	0.0496**	-0.03									
[7] Emissions Trading Schemes	0.0548***	0.0686***	0.00	-0.01	0.03	0.183***								
[8] Feed-in-tariffs (FIT)	-0.03	-0.02	-0.0342*	0.03	-0.02	0.0346*	0.0915***							
[9] Emissions Standards	0.113***	0.119***	0.0662***	0.0781***	0.0809***	0.140***	0.590***	0.414***						
[10] Green R&D Subsidies	0.0398*	0.0651***	0.03	0.139***	0.0415*	0.183***	0.315***	0.131***	0.416***					
[11] Regional GDP per Capita	0.203***	0.207***	0.166***	0.176***	0.128***	0.0880***	0.109***	0.0528**	0.257***	0.279***				
[12] Ren. Energy % Total Energy Supply	-0.0740***	-0.0771***	-0.02	-0.0963***	-0.0486**	0.00	0.127***	-0.03	0.180***	0.325***	0.0660***			
[13] Research Institutes	0.674***	0.715***	0.400***	0.398***	0.558***	0.0427**	0.0401*	-0.0534***	0.111***	0.0762***	0.329***	-0.111***		
[14] Renewable Energy Tilt	-0.01	-0.01	-0.03	0.168***	0.00	-0.145***	0.0432**	0.197***	0.193***	0.110***	0.0465**	-0.0459**	0.03	
[15] Green VC ($ million)	0.724***	0.762***	0.275***	0.231***	0.809***	-0.02	0.03	-0.01	0.0900***	0.0404*	0.101***	-0.0357*	0.466***	-0.0116

Appendix A.3. OECD Environmental Policy Stringency

The full methodology behind the OECD Environmental Policy Indices construction can be found in the report of Botta and Koźluk (2014).

The selection of policy instruments by the OECD has been done to proxy environmental policy stringency across the economy, however, the majority of policy instruments are targeted towards / cover mostly the energy sector. These include "command-and-control" type environmental policies such as emission limit values, the pricing of externalities through taxes and through trading schemes (where the yearly average price of allowance is used in the index construction). For government R&D expenditures, the OECD uses the annual total public budget allocated for R&D in green technologies as % of GDP (Botta and Koźluk, 2014). Examples of the different types of information that the OECD uses in scoring and defining stringency thresholds for granular policy instruments are illustrated below:

"For federal countries, where some of the key instruments for the energy sector are applied at the sub-national levels, these instruments are also considered (e.g. US States, Canadian Provinces). In this case, they have been weighted by the State's share of a country's total generation (or demand). In case of emission limit values, due to the problematic averaging, the emission limit value for the most populated State or Province was adopted." (Botta and Koźluk, 2014, p. 19)

Based on the information used for scoring for each policy instrument, seven classes of increasing stringency are identified (from 0, non-existing, to 6, most stringent). The values for each country are assigned based on the in-sample distribution of values for each instrument. The instrument-specific indicators (e.g. taxes on SOx, NOx and CO2) are then aggregated into mid-level indicators according to their type (e.g. environmental taxes) through equal weighting. An example of aggregation for environmental taxes can be seen below:

Appendix A.4. Robustness tests

Online Appendix

Table A.3.1
Information considered for scoring of the stringency of environmental policies. Adapted from (Botta and Koźluk, 2014)

Policy Instrument	Information considered for scoring
Emission Trading Scheme (CO_2)	Price of CO_2 allowance
Renewable Energy Certificates Trading Scheme	% of renewable electricity that has to be procured annually
CO_2 tax	Tax rate in EUR/ tonne emissions
Feed in Tariff for wind	EUR/kWh
SO_x Emission Limit Value for newly built coal-fired plant	Value of Emission Limit in mg/m^3
Renewable R&D subsidies	Expressed as % of GDP
Tax on diesel for industry	Total tax for a litre of diesel used in transport for industry
Maximum content of sulphur allowed in diesel	Value dictated by the standard

Table A.3.2
Example scoring and aggregation of country level environmental policy stringency. Adapted from (Botta and Koźluk, 2014)

EPS Policy Instrument Aggregation	EPS Granular Policy Instruments	Tax rateMWh/tonne (or per litre in case of diesel tax, deflated byEUR/MWh)	Score Assigned	Weight	Taxes Environmental Policy Stringency Score
Taxes	CO_2,	0	0	0.25	1.5
	NO_x	$0 < x <= 0.03$	1	0.25	
	SO_x	$0.03 < x <= 0.5$	2	0.25	
	Diesel	$0.5 < x <=1$	3	0.25	

Table A.4.1.
Additional start-up funding panel corrected standard error models.

Regional Start-up Funding Model	Green **6a**	Battery **6b**	Biofuels **6c**	DSFSC **6d**	EEff **6e**	EV **6f**	Generation **6g**	Grid **6h**	Materials **6i**
Taxes	-0.343	-0.073	-0.036	-0.164***	-0.135	-0.079	-0.171	-0.112**	-0.163
	(0.217)	(0.069)	(0.064)	(0.047)	(0.087)	(0.049)	(0.109)	(0.034)	(0.118)
Trading_Schemes	-0.108	0.003	-0.056+	-0.014	-0.030	-0.034*	-0.079	-0.015	-0.034
	(0.103)	(0.028)	(0.032)	(0.026)	(0.034)	(0.017)	(0.055)	(0.017)	(0.046)
FIT	0.204***	0.030+	0.055***	0.047**	0.031+	0.014+	0.103***	0.027**	0.075***
	(0.055)	(0.016)	(0.015)	(0.016)	(0.016)	(0.007)	(0.027)	(0.009)	(0.021)
Standards	0.584***	0.082+	0.157***	0.120**	0.147**	0.143***	0.298***	0.099***	0.260***
	(0.125)	(0.042)	(0.046)	(0.037)	(0.055)	(0.030)	(0.072)	(0.025)	(0.067)
RD_Subsidies	0.079	0.052	-0.036	-0.013	-0.003	0.037	0.068	0.017	0.051
	(0.152)	(0.040)	(0.041)	(0.035)	(0.055)	(0.030)	(0.072)	(0.023)	(0.076)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES
Num. obs.	3809	3809	3809	3809	3809	3809	3809	3809	3809
Adj. R^2	0.5926	0.5229	0.4259	0.3918	0.5583	0.3645	0.4402	0.3552	0.5160

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, +$p < 0.1$. New start-up financing log-normal OLS models. Dependent variable is the natural logarithm of the total regional green start-up funding in a given year in $ million, including across green sub-sectors. Dataset is a balanced regional panel over 2001 – 2013 and includes year and regional fixed effects. Independent variables are lagged 1 year. Panel corrected standard errors (PCSE) in parentheses.

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