Entrepreneurial ecosystems' transition to sustainability: exploring the demand for green talents in 20 global cities

Abstract

This paper contributes to the study of entrepreneurial ecosystems (EEs) and their transition to sustainability by investigating their demand for Green Talents as a fundamental resource and an enabling factor for this shift. Scholars have previously employed the concept of EEs to account for the contextual, evolutionary, and nonlinear features of entrepreneurship in countries, regions, and cities. There, Talents constitute one of the fundamental sources for growth and innovation, specifically in the transition to more sustainable practices for which individual businesses and EEs alike need to recruit workers possessing specific technical and analytical skills and knowledge, often named "Green Talents". Despite this relevance, the demand for Green Talents in city EEs has never been investigated. To fill this gap, the present explorative paper committed to assess the demand for Green Talents in city EEs, reveal recurring patterns, and identify potential predicting factors. Drawing on the Quadruple/Quintuple Helix Framework, on multiple streams in economics and management, and on Startup Genome 2022 List of city ecosystems, this work identified 20 EEs hosting the most advanced communities of entrepreneurs in the world. Then, from these ecosystems it collected almost 3.5 million OJVs published in the month of November 2022, and quantitatively analyzed them with statistical techniques. It found that the percentage of OJVs dedicated to Green Talents remains relatively low at 1.53% on average, but with major differences between industrial sectors and job functions. Specifically, heavy and environmentally impactful sectors such as Construction, Mining and oil, and Utilities are investing much in recruiting Green Talents to implement more sustainable practices. Additionally, local EE factors appear to influence the demand for Green Talents via OJVs, whether negatively such as EE Performance and green

Talent availability, or positively such as availability of green Knowledge, Funding, or EE Focus on green enterprises. These last results confirm the importance of context and non-linear dynamics for entrepreneurship at the city level. Accordingly, this preliminary work contributes to the literature with first empirical results on the demand for Green Talents in EEs, and further confirms existing theories on ecosystem entrepreneurship at the city level. Moreover, this data could be used to benchmark cities and sectors or support data-driven policies for the acquisition of Green Talents and favor EE synergies, ultimately fostering the transition of EEs to sustainability.

Keywords

Entrepreneurial Ecosystem; Green Talent; Online Job Vacancy; Green Skill; Quadruple Helix

Introduction

Entrepreneurial ecosystems (EEs) are growing in terms of quantity, diversity, and relevance to the economy and society (Theodoraki, Dana, and Caputo 2022). Based on the 2022 global report issued by Startup Genome, at least 300 emerging ecosystems can be identified globally, each with unique characteristics, compositions, resources, and specializations (Startup Genome 2022b). The composition of EEs is enriched by different entities such as corporations, small and medium enterprises, startups, and incubators, across a variety of emerging technologies and sectors (Cavallo, Ghezzi, and Balocco 2019; Theodoraki, Messeghem, and Audretsch 2022). Specifically, entrepreneurs and their startups' prosperity increasingly derives from the health, richness of resources, and interconnectedness of the local ecosystem, as innovation and entrepreneurship increasingly rely on distributed, complementary, and complex functions (Feld 2020). Moreover, they contribute back to their ecosystem by providing infrastructure, financial resources, and human capital that foster local innovation and development, thus sustaining a virtuous cycle and the birth of more startups (Acs and Armington 2004; Kasturi and Subrahmanya 2014). As they enlarge, EEs have impacts beyond the local boundaries, and increasingly so due to the digitalization and remotization of the economy (Cukier and Kon 2018; Dabić et al. 2020).

Yet, EEs and their local actors are currently challenged by the urgency to transform their practices, processes, and products to reduce their detrimental impact on society and the environment (Audretsch et al. 2019). This is also relevant in light of the United Nations' 2030 Agenda: as governments fall short in pursuing the Sustainable Development Goals (SDGs) and dealing with their complexity (Hickmann et al. 2022; Biermann et al. 2022; Spinazzola and Cavalli 2022), bottom-up innovation and entrepreneurship may be fundamental to drive the achievement of multiple SDGs, including SDG 4 – Quality Education, SDG 8 – Decent Work and Economic Growth, SDG 9 – Industry, Innovation, and Infrastructure, SDG 11 – Sustainable Cities and Communities (Cordova and Celone 2019; Walsh, Murphy, and Horan 2020). Hence, scholars have attempted to analyze the importance of sustainable entrepreneurial ecosystems (Theodoraki, Dana, and Caputo 2022; DiVito and Ingen-Housz 2021; O'Shea, Farny, and Hakala 2021; Pankov, Velamuri, and Schneckenberg 2021).

To develop more sustainable EEs, additional and specific resources would need to be acquired, ultimately aiming to initiate self-reinforcing dynamics within EEs (Stam and van de Ven 2021; Pelinescu 2015; Carayannis et al. 2018). Crucially, these would include the recruitment of Green Talents possessing adequate knowledge, skills, abilities, attitudes, behavior and awareness to drive this transformation to sustainability (Cabral and Lochan Dhar 2019; Glen, Hilson, and Lowitt 2009). Hence, public and private actors are moving to understand and nurture the provision and attraction of Green Talents (ESCO 2022; European Training Foundation 2022), and some initial studies in this regard have been produced, specifically on sectors such as construction (Hamzeh et al. 2019), e-waste management (Bozkurt and Stowell 2016), and education (McGrath and Powell 2016). Nonetheless, there is still a lack of systemic understanding on necessary need for talents possessing green skills and knowledge, particularly at the level of EEs (Odugbesan et al. 2022; Ogbeibu et al. 2022, 2021; Carayannis et al. 2018)

To fill this gap, the present paper aims to assess the demand for Green Talents in city EEs, explore recurring patterns, and ultimately identify potential predicting factors. First, it was designed drawing on the Quadruple/Quintuple Helix Framework and from multiple streams in evolutionary economics, regional development, and entrepreneurship (Carayannis, Barth, and Campbell 2012; Carayannis et al. 2018). Then, after identifying 20 leading city EEs from the most recent Startup Genome report (Startup Genome 2022b), almost 3.5 million online job vacancies (OJVs) published in in the month of November 2022 were retrieved and quantitatively analyzed (European Training Foundation 2022; Lovaglio et al. 2018).

It was found that the percentage of OJVs for Green Talents remains relatively low, at 1.53% on average, but differences between industrial sectors and job functions were identified: heavy and environmentally impactful sectors such as Construction, Mining and oil, and Utilities are more intensively investing in recruiting Green Talents to implement more sustainable practices. The Corporate services sector also emerges as a highly recruiting one, possibly working as a EE facilitator in the provision of Green Talents via body rental (LinkedIn 2022; Sern, Zaime, and Foong 2018). Moreover, the demand for Green Talents results higher for Manufacturing, Analytical, and Business jobs than to other types, in line with the relevance of technical and analytical skills and the leading role played by the heavy sectors. Additionally, local EE factors appear to influence the demand for Green Talents via OJVs, whether negatively such as EE Performance and green Talent availability, or positively such as availability of green Knowledge, Funding, or EE Focus on green enterprises. These last results confirm the importance of context and non-linear dynamics for entrepreneurship at the city level (Stam and van de Ven 2021; Cavallo, Ghezzi, and Balocco 2019).

These analyses contribute to the literature with initial empirical insights on the demand for Green Talents. Moreover, they confirm the importance of employer-specific and EE-specific factors, despite hinting at previously undetected negative feedback in EEs. Being crucial for the growth of ecosystems and their transition to sustainability, additional data-intensive research is necessary to shed light on them (Carayannis et al. 2018; Theodoraki, Dana, and Caputo 2022). This paper also provides first practical insights on the current demand for Green Talents, which may be further expanded in the prosecution of this work. Specifically this data could be used for benchmarking between cities and sectors (Startup Genome 2022a) and to support data-driven policies for the acquisition of Green Talents and favor EE synergies, ultimately fostering the transition of EEs to sustainability (Hausmann et al. 2014; Carayannis et al. 2018).

Theoretical background

Though discussed since the Nineties, only in the last decade the concept of EE has seen empirical diffusion and advancements in theorization (Cavallo, Ghezzi, and Balocco 2019). As for other strictly connected terms such as business ecosystem (Moore 1993; Iansiti and Levien 2004), or innovation ecosystem (Clarysse et al. 2014; Zahra and Nambisan 2011), it expands the focus from the heroic entrepreneur to its environment, thus including also the entrepreneur's relationship with peers and other diverse actors. Accordingly, the concept points to the major relevance that communities, culture, and interactions have on the chances of entrepreneurial success, and constitutes a highly contextual, evolutionary, and nonlinear perspective on entrepreneurship (Stam and Spigel 2016; Feld 2020). In these terms, it has been used to investigate different contexts and levels, including regional EEs (Fritsch 2013; Tsvetkova 2015) and city EEs (Mack and Mayer 2016; Spigel 2017).

Drawing from the recent work of Stam and van de Ven (2021), an EE could be analytically organized into three main institutional pillars, and namely Formal institutions, Culture, and Networks, each contributing to the ecosystem with endowments such as Physical infrastructure, Demand for products or services, Service intermediaries, Talents, Knowledge, Leadership, and Finance. These are the equivalent of abiotic resources (e.g. nutrients, water, rocks) available in a natural ecosystem to the multiplicity of species that inhabit it (Stam and Spigel 2016). As living beings metabolize these resources to grow and replicate, so do entrepreneurs and enterprises, as they combine them to generate innovations, compete with each other, and scale up, and often contribute back to their ecosystem with additional knowledge, talents, and funding, or other resources (Stam and van de Ven 2021; Carayannis et al. 2018).

In this environment, diverse actors including corporations, small and medium enterprises, startups, but also governmental bodies, universities, research centers, and customers interact, both in competitive and collaborative ways (Cavallo, Ghezzi, and Balocco 2019; Carayannis et al. 2018; Theodoraki, Messeghem, and Rice 2018). While this is the same fundamental principle also behind innovation ecosystems and the two concepts are often overlapping, the main difference here is on the output of these dynamics: where innovation ecosystems are assessed primarily measuring novel products, services, or processes as output, EEs' Performance is assessed measuring new enterprises (Stam and van de Ven 2021). Accordingly, as for other types of ecosystems, EEs are significantly dependent on the availability of sufficient resources and functionally complementary actors, hence justifying the focus on local contexts (Stam 2015; Colombelli, Paolucci, and Ughetto 2019). While mere spatial distance are likely to be of less relevance in the future due to the progressive expansion of business and innovation networks as well as to digitalization (Florida, Adler, and Mellander 2017; Z. J. Acs et al. 2017), context still remains of great relevance as entrepreneurship emerges from a combination of global as well as local forces (Del Giudice, Carayannis, and Maggioni 2017; Bereznoy, Meissner, and Scuotto 2021).

Theoretical framework and hypotheses

To investigate the role of Green Talents in the sustainability transition of EEs, this paper combines concepts from different literature streams in evolutionary economics, regional development, and entrepreneurship, which ultimately converge in the Quadruple/Quintuple Helix Framework (Carayannis, Barth, and Campbell 2012; Carayannis et al. 2018; Cloitre, Dos Santos Paulino, and Theodoraki 2022). This metatheory is here employed as a cornerstone framework for multiple reasons: it is often used to investigate innovation and entrepreneurship from an ecosystem perspective; accounts for a variety of ecosystem actors and resources, including talents, and their interactions; effectively contextualizes these phenomena in current sustainability challenges and transitions (Theodoraki, Dana, and Caputo 2022).

Among the necessary resources, talents are of the most crucial. With an increasing relevance of immaterial input in the value of products and services, organizations increasingly rely on their workers to innovate, compete and thrive, and so do ecosystems (Arruda, Nogueira, and Costa 2014; Unger et al. 2011). From an ecosystem perspective, talents are particularly interesting: workers collects knowledge, skills, and experience during all along their life moving through mandatory and often publicly funded education, to tertiary education or university, and then from one organization to the other (Laroche, Mérette, and Ruggeri 1999); their availability is limited and often concentrated in specific organizations or locations where a leading university or industrial cluster is located (Hausmann et al. 2014; Gallié et al. 2013); thanks to the combined effort of different actors, in an healthy ecosystem, they tend to accumulate knowledge and skills over time, thus working both as a resource and as a byproduct (Ancori 2000; Carayannis et al. 2018; Clarysse et al. 2014). These characteristics massively benefit density, making highly populated cities among the most innovative and entrepreneurial hotspot in the world (Binz, Truffer, and Coenen 2014; Startup Genome 2022b).

These factors make the acquisition of new talents extremely difficult (Hausmann et al. 2014), particularly when enterprises or ecosystems undergo major internal transformation, such as for the adoption of novel technologies or responding to new internal or external challenges. One such example is the transition to sustainability that businesses, industries, and ecosystems are currently undergoing (Pelinescu 2015). This calls for a new kind of talents, Green Talents, defined as workers possessing analytical and technical knowledge and skills related to the design, monitoring, production, and improvement of environmentally-impactful products or processes a (Glen, Hilson, and Lowitt 2009; Vona et al. 2015; Sern, Zaime, and Foong 2018). Examples include fully sustainability-oriented professions such as Wind turbine technicians, Solar consultants, Sustainability managers, Environmental, health, and safety specialists, as well as professionals for which the possession of green skills and knowledge has only recently emerged, such as Compliance managers, Risk advisors, Sales representatives, and so on (LinkedIn 2022; ESCO 2022; Glen, Hilson, and Lowitt 2009). Indeed, climate change and environmental degradation are already motivating public and private actors to increase investments to finance green infrastructure, R&D in green technologies, and training in green skills. These forces are already challenging established businesses to transform, as well as opening opportunities for innovative startups to develop better products, services, or processes (Carayannis, Barth, and Campbell 2012; Hockerts and Wüstenhagen 2010; Vona et al. 2015).

At the level of city EEs, acquiring Green Talents would be fundamental to enable this transition, but this attempt is likely to depend on a number of antecedent factors, such as the availability of local universities specialized in the provision of green knowledge and talents, availability of dedicated finance, as well as the pre-existing performance of the ecosystem in green sectors (Pelinescu 2015; Stam and van de Ven 2021; Mack and Mayer 2016). Indeed, if sufficient positive feedbacks between ecosystem actors emerged, this may initiate synergies in the acquisition of additional Green Talents and foster the transition of the EEs to sustainability (Carayannis et al. 2018).

Accordingly, Figure 1 depicts the theoretical framework of this research and the variables used in the following analyses. Within the overarching pressure of environmental and social challenges (Carayannis, Barth, and Campbell 2012; Carayannis et al. 2018), the demand for Green Talents results from the combined influence of EE factors and employer-specific factors. First, the employer's industry and required job function are expected to determine the likelihood of finding Green OJVs, with some industries clearly more involved with recruiting workers with greens skills and for specific positions. More information in this regard is provided in the Discussion (LinkedIn 2022; Sern, Zaime, and Foong 2018). Second, EE factors are also expected to influence the demand for Green Talents. Specifically, drawing on Stam and van de Ven's conceptualization (2021), a distinction can be made: on the one hand, availability sustainability-relevant resources such as Funding, Knowledge, and Talents; on the other, EE outputs, such as the overall Performance in generating new enterprises and the Focus of these enterprises on sustainability. More information on these variables is provided in the Methodology (Stam and van de Ven 2021; Acs et al. 2017; Startup Genome 2022a). Accordingly, the following two hypotheses are developed:

- *H1 Employer-specific factors influence the demand for Green Talents*
- *H2. Local EE factors influence the demand for Green Talents*

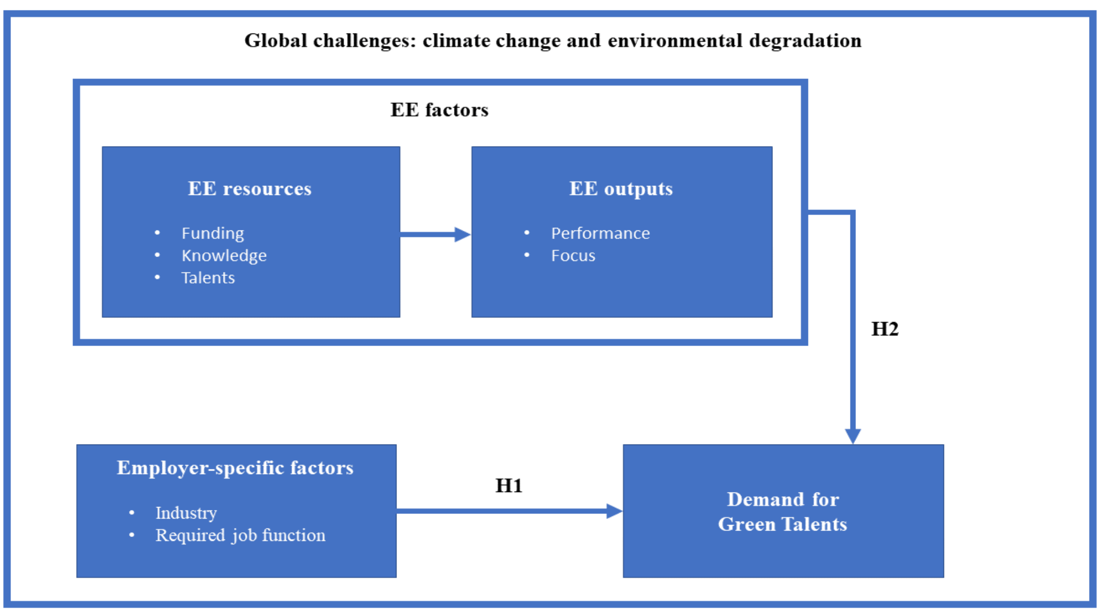

Figure 1. Theoretical framework (own work)

Materials and methods

For this study, Online Job Vacancies (OJVs) were employed as the main source of material. A large share of recruiting currently happens on the web, where companies regularly post their job vacancies on dedicated social networks and platforms and workers actively search for them (Nakamura et al. 2009). Usage of these platforms varies according to regions and industrial sectors, with higher values (above 50% of the working population) in North America and Europe for professionals in Information and communication technologies, Mining and quarrying, and other highly technical industries (Zhu, Fritzler, and Orlowski 2018). Consequently, previous studies have shown that OJVs tend to over-represent white collar job opportunities destinated to candidates with high skills in STEM disciplines (Carnevale, Jayasundera, and Repnikov 2014). Nonetheless, for the global reach, extensiveness of these platforms (LinkedIn n.d.; Indeed n.d.) and the richness and time-sensitivity of data on locations, employers, required skills, etc., OJVs are increasingly used by academia as well as public and private organizations to investigate job markets and industry trends (Beblavý, Fabo, and Lenaerts 2016; Faryna et al. 2022; Nakamura et al. 2009; European Training Foundation 2022; European Commission 2021). Accordingly, this work assumes that the demand for professionals with green skills in OJVs may be used as a proxy for the tentative acquisition of Green Talents (Lovaglio et al. 2018; OECD and CEDEFOP 2014).

Publicly available OJVs published on in the month of November 2022 were collected from a major US-based platform and then analyzed (Lovaglio et al. 2018). First, Startup Genome 2022 list of city ecosystems was employed to identify the 20 most advanced communities of entrepreneurs, mostly consisting of large and rich metropolitan areas in North America, Europe, and East Asia (Startup Genome 2022b). This list was used to define the geographical boundaries of this study and customize the data collection by retrieving solely OJVs relevant for the selected metropolitan areas. Additionally, available platform's filters were used to label vacancies during the data collection. Each OJV was assigned to one out of nineteen industry sectors and to one out of seven job functions. Moreover, relying on the platform dedicated filter, OJVs for which green skills and knowledge were required could be distinguished from all others: hence, the first group was labeled as Green OJVs and the latter as Non-green OJVs (Table 1).

Table 1. Categorical OJV variables

Industry	**Industry**	**Job**	**Green**
Agriculture	Health	Administrative	Green
Arts	Legal	Analytical	Non-green
Biotechnology	Manufacture	Business	
Construction	Mining and oil	Creative	
Consumer goods	Technology	Educational	
Consumer services	Technological manufacturing	Manufacturing	
Corporate services	Transports	Other	
Education	Utilities		
Finance and banking	Other		
Government			

Collecting this information provided an extensive dataset of almost 3.5 million OJVs (Table 2). As shown in the table, the number of vacancies in each ecosystem varied massively, from 7,333 in Seoul and 8,435 in Tel Aviv up to 349,632 in Los Angeles and 471,392 in New York. These differences likely resulted from differences in the size and economic structure of cities, as well as on the penetration of the platform in different regions (Zhu, Fritzler, and Orlowski 2018).

Accordingly, to avoid biases and foster inter-ecosystem comparability, during the analyses values were often normalized.

Table 2. Startup Genome top 20 ecosystems

Ecosystem	**Startup Genome Ranking**	**OJVs**
Silicon Valley	1	220,419
London	2 (tie)	259,632
New York City	2 (tie)	471,392
Boston	4	310,573
Beijing	5	108,680
Los Angeles	6	349,632
Tel Aviv	7	8,435
Shanghai	8	108,847
Seattle	9	237,556
Seoul	10	7,333
Washington, D.C.	11	295,307
Tokyo	12	83,797
San Diego	13	190,288
Amsterdam-Delta	14	72,135
Paris	15	162,037
Berlin	16	83,168
Toronto-Waterloo	17	51,734
Singapore	18	71,179
Chicago	19	310,715
Sydney	20	43,888
Total number of OJVs		**3,446,747**

Then, information on the industrial sector, the job function, and the request for green skills and knowledge was quantitatively analyzed in the open source software R Studio (R Studio n.d.). Descriptive statistics were calculated to obtain variable-specific insights and compare results across ecosystems. Specifically, the Euclidean distance between values was computed and represented in EE-normalized heatmaps with dendrograms. Interpreting this representation, and particularly the length of dendrogram branches (the longer the branches the more different two variables are), allowed to explore existing patterns and search for potential clusters (Forina, Armanino, and Raggio 2002; Pai 2021).

Next, attempting to identify the variables with the highest influence on the publication of Green OJVs, a logistic regression model was built. As other linear regressions, it builds a linear equation of multiple independent variables to explain or predict the response of a single dependent one. Specifically, in a logistic regression the dependent variable is binomial (can either take value 0 or 1, in this case an OJVs can either be Green or Non-green) and is measured as the odds ratio between the two alternative outcomes. Accordingly, manipulating the coefficients of the regression equation, the logistic regression allows to calculate variations in the probability of the dependent variable's response being "1" (or Green, in the case of OJVs) due to the influence of each independent variable (Sperandei 2014; Strzelecka, Kurdyś-Kujawska, and Zawadzka 2020).

For the purpose of this study (Figure 1), other than information extracted from the OJVs, information on local EE factors were also included. Relying on Startup Genome's indicators published in the 2022 Cleantech report (Startup Genome 2022a), five key variables were considered: Performance (measured as the number of relevant startup exits in the EE), available Funding in the EE, available Knowledge (measured as the number and variety of relevant patent classes) available in the EE, available Talents (measured as the number of graduates in relevant disciplines) in the EE, and EE Focus (measured as the percentage of relevant startups over the total number of startups) in the EE (Table 3). Further methodological information can be found in the Cleantech report (Startup Genome 2022a). When a city EE was not included in the report, related OJVs were removed from the logistic regression.

Table 3. Startup Genome cleantech indicators

Ecosystem	Performance	Funding	Knowledge	Talent	Focus
Silicon Valley	10	10	8	10	3
New York City	8	10	6	5	1
London	9	10	4	8	4
Boston	9	10	5	8	7
Beijing	9	4	10	6	1
Los Angeles	10	9	7	8	3
Tel Aviv	10	8	10	3	6
Shanghai	NA	NA	NA	NA	NA
Seattle	2	7	9	10	4
Seoul	NA	NA	NA	NA	NA
Washington, D.C.	8	8	2	7	5
Tokyo	NA	NA	NA	NA	NA
San Diego	6	2	9	4	4
Amsterdam-Delta	8	9	1	7	8
Paris	7	7	2	5	2
Berlin	7	8	3	4	6
Toronto-Waterloo	4	9	10	9	5
Singapore	1	3	3	2	10
Chicago	NA	NA	NA	NA	NA
Sydney	6	4	6	5	4

Preliminary results

From the preliminary analyses, it was found that only 52,034 (1.53%) of all OJVs required green skills or knowledge. This number ranged from 48 (0.57%) in Tel Aviv, 206 (2.89%) in Seoul, 692 (0.83%) in Tokyo, 738 (1.03%) in Amsterdam, 1,070 (2.50%) in Sydney, 1,074 (2.12%) in Toronto-Waterloo, 1,208 (1.47%) in Berlin, 1,324 (1.90%) in Singapore, 1,440 (1.34%) in Shanghai, 1,732 (1.62%) in Beijing, 2,322 (1.45%) in Paris, 2,656 (1.42%) in San Diego, 2,953

(1.36%) in the Silicon Valley, 3,659 (1.56%) in Seattle, 4,269 (1.47%) in Washington D.C., 4,370 (1.71%) in London, 4,562 (1.49%) in Chicago, 5,593 (1.83%) in Boston, 5,686 (1.65%) in Los Angeles, and 6,432 (1.38%) in New York. Accordingly, New York, Los Angeles, and Boston emerge as the cities posting the largest number of Green OJVs in absolute terms, while in relative terms this position is taken by Seoul, Sydney, and Toronto-Waterloo. Regardless of these differences, demand for Green Talents remains small and in relative terms displays only limited variations across ecosystems (Figure 2).

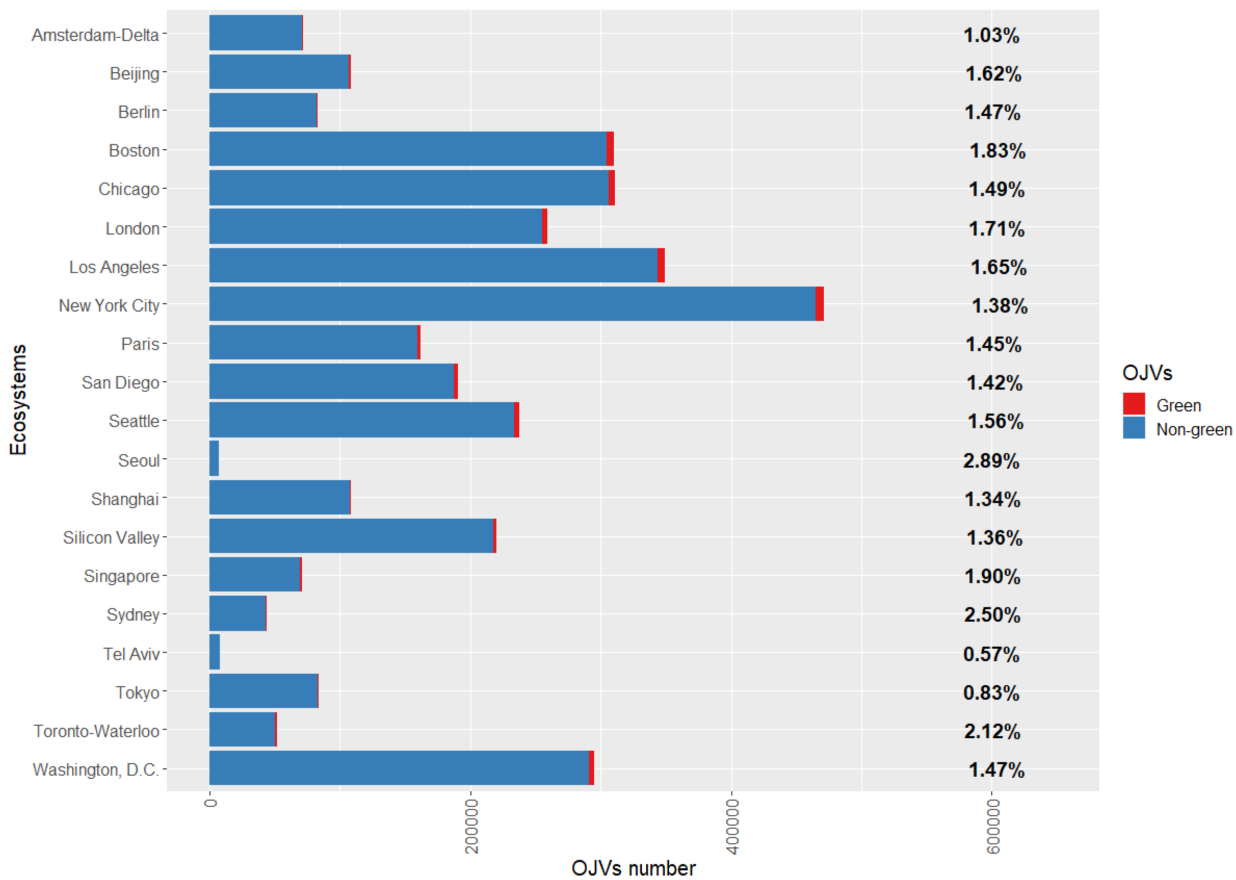

Figure 2. Ecosystems and OJVs (own work)

Conversely, demand for Green Talents appears to vary more significantly depending on the industry. Results range from 167 Green OJVs (0.66%) for the Legal sector, to 522 (3.04%) for Agriculture, to 792 (1.50%) for Technological Manufacturing, to 839 (1.95%) for Transportation, to 866 (0.34%) for Finance, to 933 (0.41%) for Consumer Goods, to 1,202 (0.55%) for Health, to 1,214 (1.20%) for Education, to 1,222 (1.70%) for Arts, to 1,352 (0.52%) for Consumer Services, to 1,382 (2.77%) for Government, to 1,708 (1.31%) for Biotechnology, to 3,249 (12.88%) for Mining and oil, to 3,341 (0.38%) for Technology, to 4,384 (2.85%) for Manufacturing, to 6,110 (19.30%) for Utilities, to 10,114 (6.67%) for Construction, and 11,880 (1.92%) for Corporate services. Accordingly, Corporate services, Construction, and Utilities display the highest number of Green OJVs, but in relative terms this value is also high for Mining and oil (Figure 3a). These results appear consistent also across ecosystems (Figure 3b). Moreover, one macro cluster of predominantly US-based EEs is possibly identified (New York, Los Angeles, Boston, London, Washington, D.C., Seattle, and Chicago), indicating a stronger similarity in industrial patterns between these cities than with the remaining EEs (Figure 3b).

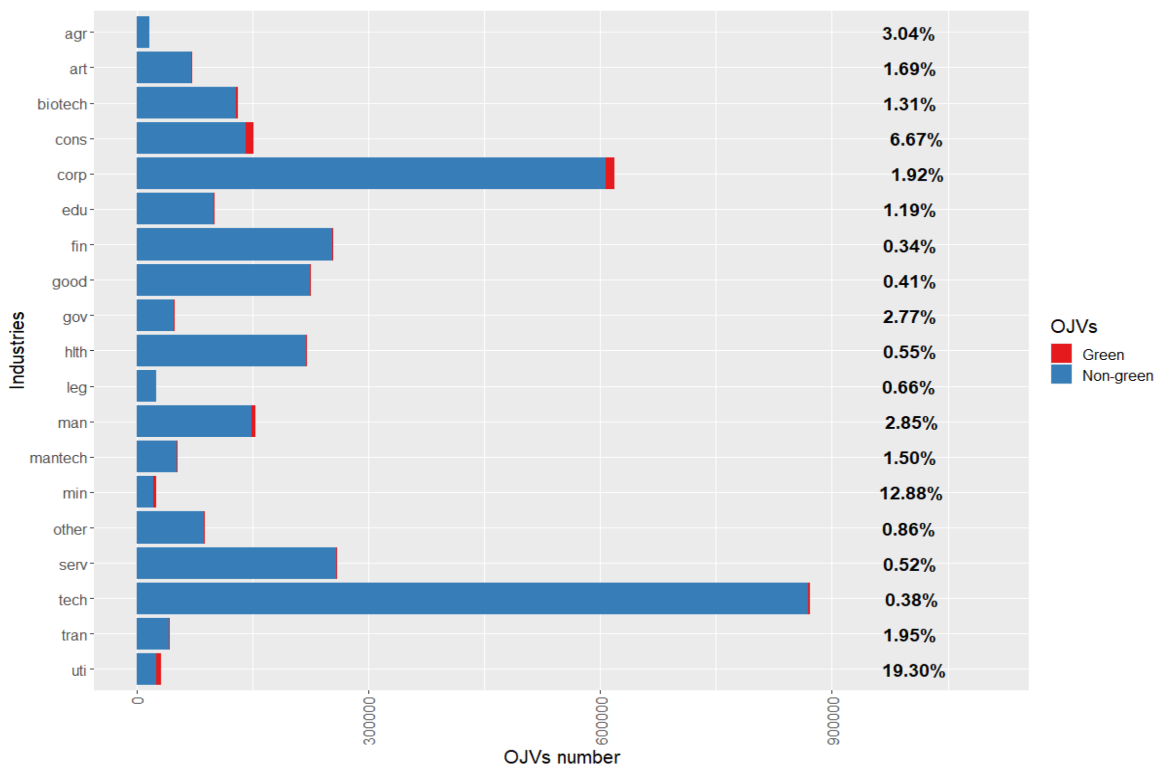

Figure 3a. OJVs by industry (own work)

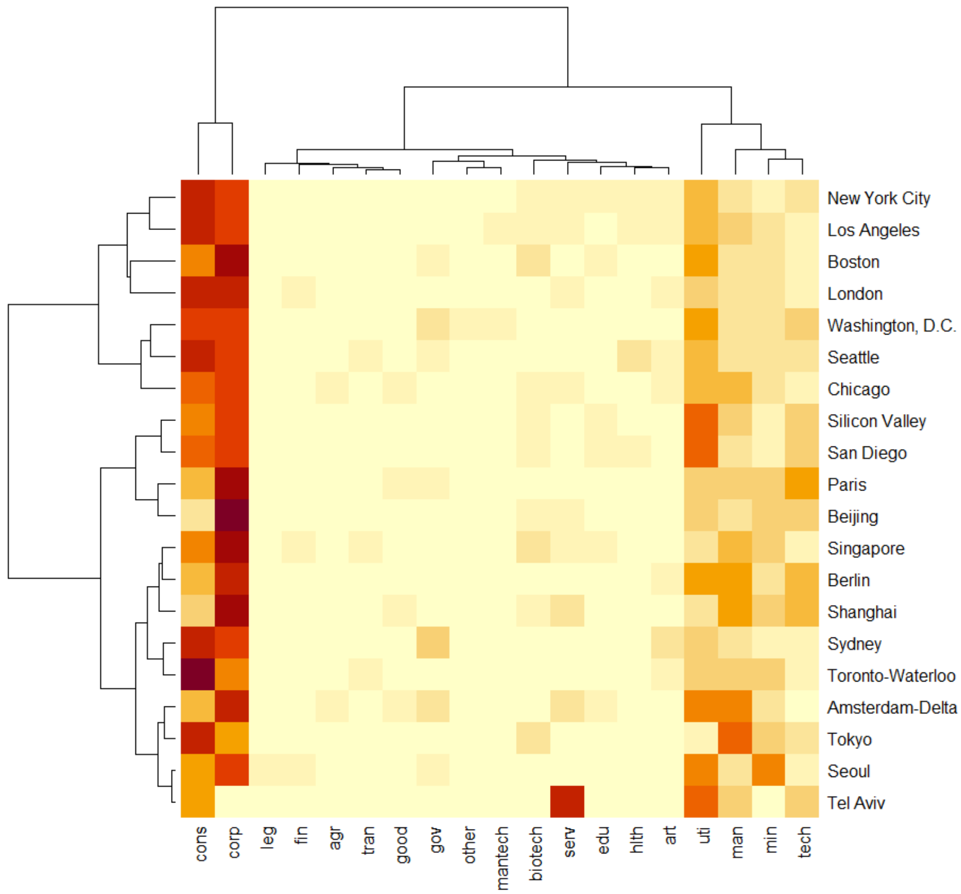

Figure 3b. OJVs by industry and ecosystem (own work)

These results suggest a strong demand for Green Talents in traditionally heavy sectors, which is possibility confirmed by the analysis of the job functions most searched. Indeed, 361 (0.39%) are in Education, 1,694 (0.66%) are Administrative positions, 1,904 (1.77%) are Creative positions, 7,958 (3.36%) are Manufacturing positions, 16,316 (1.61%) are Analytical positions, 16,391 (2.23%) are in Business, and 7,777 (0.78%) fall in the "Other" category. Hence, the relevance of Manufacturing, Business, and Analytical jobs emerges both in absolute and relative terms (Figure 4a). Once more, these results appear consistent also across ecosystems, but no real cluster for EEs can be identified (Figure 4b).

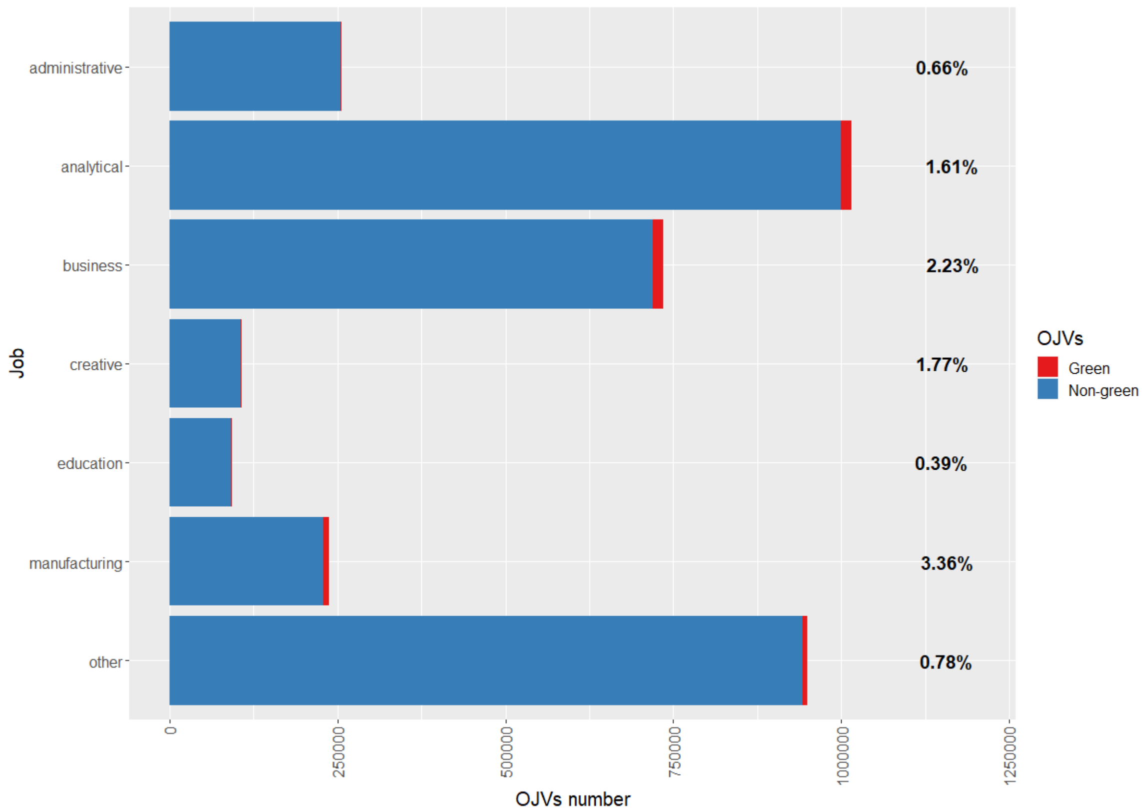

Figure 4a. OJVs by job function (own work)

To assess how these variables cumulatively influence the publication of Green OJVs, a logistic regression model was built. After testing for multicollinearity (Table 4), the total explanatory power of the model was assessed employing the McFadden pseudo-R^2 test. It provided an output of 0.138, hence indicating that the current model is able to explain only a portion of the variance in the data. Nonetheless, the current model effectively identifies a multiplicity of local EE and employer-specific factors as statistically significant in determining the probability of publishing OJVs to acquire new Green Talents (Table 5).

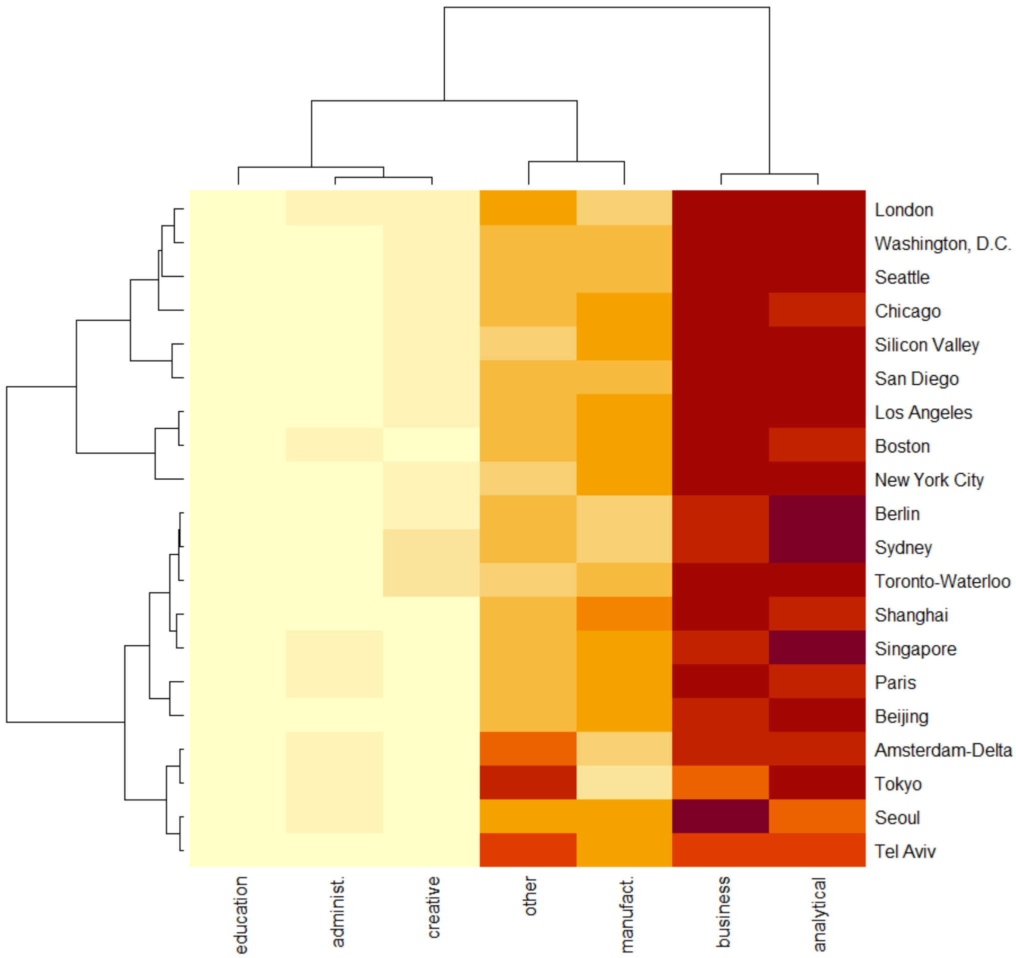

Figure 4b. OJVs by job function and ecosystem (own work)

Table 4. Multicollinearity test

Factors	**GVIF**	**Df**	**GVIF^(1/(2*Df))**
Performance	1.530689	1	1.23721
Funding	2.452816	1	1.566147
Knowledge	2.102527	1	1.450009
Talent	2.049222	1	1.43151
Focus	1.593256	1	1.262242
Job	1.130392	6	1.010266
Industry	1.176764	18	1.004532

Table 5. Logistic regression output

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-4.850	0.067	-71.872	0.000	***
Performance	-0.014	0.002	-5.880	0.000	***
Funding	0.029	0.003	9.207	0.000	***
Knowledge	0.037	0.003	13.845	0.000	***
Talent	-0.0098	0.0034	-2.9147	0.004	*
Focus	0.022	0.003	7.946	0.000	***
Job:analytical	0.977	0.028	35.247	0.000	***
Job:business	1.140	0.028	41.128	0.000	***
Job:creative	0.948	0.037	25.983	0.000	***
Job:education	-0.1496	0.0627	-2.3859	0.017	.
Job:manufacturing	1.412	0.029	48.310	0.000	***
Job:other	0.304	0.029	10.398	0.000	***
Industry:art	-0.471	0.061	-7.698	0.000	***
Industry:biotech	-0.664	0.059	-11.278	0.000	***
Industry:cons	0.921	0.054	17.126	0.000	***
Industry:corp	-0.288	0.054	-5.371	0.000	***
Industry:edu	-0.581	0.061	-9.532	0.000	***
Industry:fin	-1.935	0.064	-30.281	0.000	***
Industry:good	-1.909	0.065	-29.590	0.000	***
Industry:gov	0.1285	0.0598	2.1477	0.032	.
Industry:hlth	-1.331	0.061	-21.834	0.000	***
Industry:leg	-1.074	0.098	-10.953	0.000	***
Industry:man	0.0487	0.0554	0.8782	0.380	
Industry:mantech	-0.634	0.064	-9.859	0.000	***
Industry:min	1.573	0.057	27.825	0.000	***
Industry:other	-0.999	0.065	-15.370	0.000	***
Industry:serv	-1.745	0.061	-28.807	0.000	***
Industry:tech	-1.924	0.056	-34.375	0.000	***
Industry:tran	-0.253	0.065	-3.922	0.000	***
Industry:uti	1.915	0.055	34.964	0.000	***

After transforming the coefficient values from Table 5 into odds ratios, Figure 5 allows to easily visualize them, hence deriving the influence of each factor on the probability of an OJV being directed to Green Talents or not. Starting from EE variables, it was found that every unitarian increase in the Performance of the EE decreases this probability by -1.43% (p-value < 0.000) and that increases in Talent availability decrease it by -0.97% (p-value < 0.05), while availability of

Funding increases the same probability by +2.94% (p-value < 0.000), availability of Knowledge by +3.80% (p-value < 0.000), and EE Focus increases it by +2.24% (p-value < 0.000).

Moving to the Job functions, compared to Administrative ones, OJVs for Manufacturing positions display a +310.45% increase in probability (p-value < 0.000), followed by +212.59% increase of Business ones (p-value < 0.000), by +165.54% increase of Analytical ones (p-value < 0.000), and by +158.18% increase of Creative ones (p-value < 0.000). Last, in comparison to the Agriculture sector, a major increase of +578.91% for Utilities (p-value < 0.000) is observed, of +382.04% for Mining and oil (p-value < 0.000), and of +151.25% for Construction (p-value < 0.000). Despite the high absolute values of Green OJVs, Corporate services displays a -25.01% (p-value < 0.000), and additional underperforming sectors include Finance and Banking (-85.86%, p-value < 0.000), Technology (-85.40%, p-value < 0.000), Consumer Goods (-85.18%, p-value < 0.000), Consumer Services (-82.53%, p-value < 0.000), Health (-73.58%, p-value < 0.000), and Legal (-65.82%, p-value < 0.000).

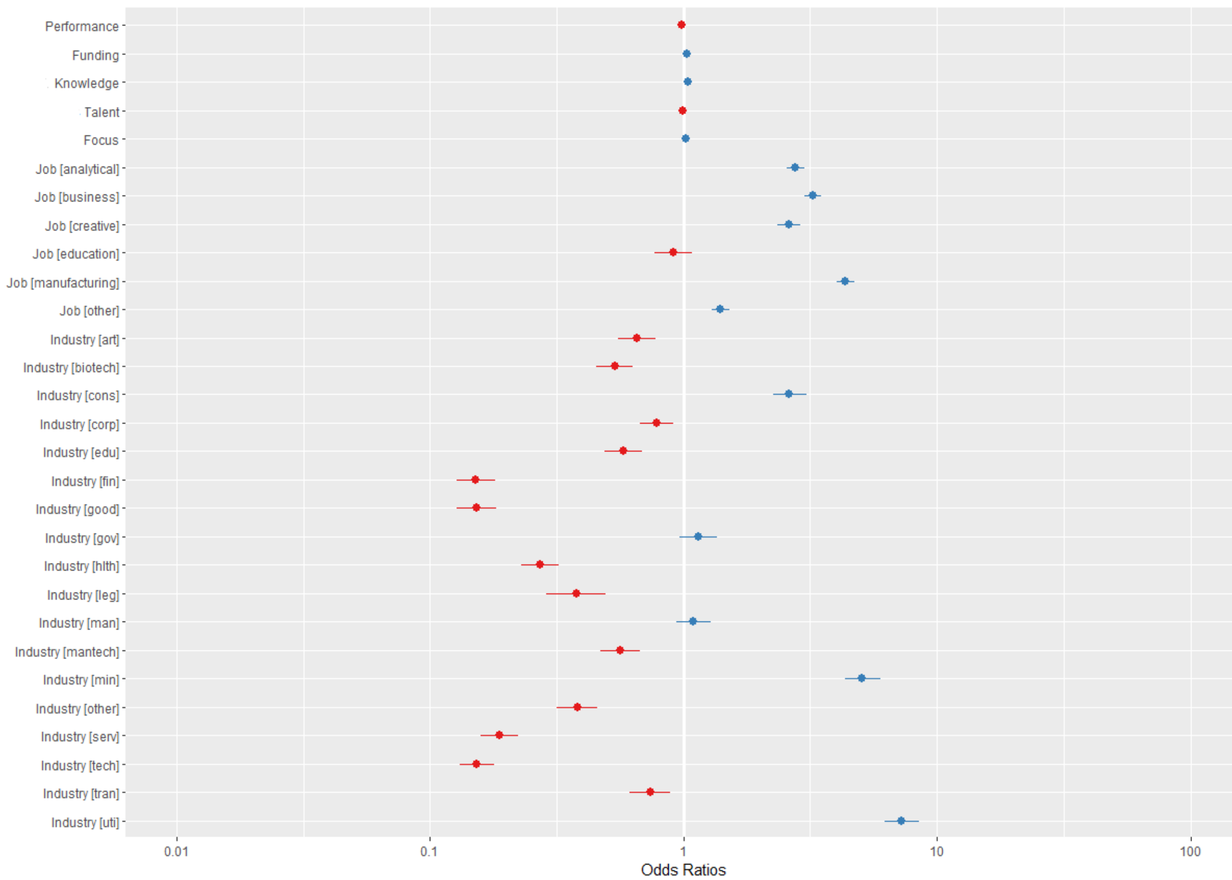

Figure 5. Plotted odds ratio (own work)

Discussion

This preliminary analysis provides interesting insights into the demand for Green Talents. First, though countries and cities vary significantly in their advancement to sustainability and availability of resources, including Green Talents (Sachs et al. 2021; OECD and CEDEFOP 2014), EEs appear to differ only slightly from each other in their demand for Talents with green skills and knowledge. This may be explained by the decision to focus on a relatively small sample of top-tier ecosystems, that may hence be more similar to each other than to the countries hosting them (Startup Genome 2022a; LinkedIn 2022).

Second, comparing a diverse set of industries, it was found that traditionally heavy and environmentally impactful sectors such as Construction, Mining and oil, and Utilities, are investing massively in recruiting Green Talents. As they already are among the industries with the highest percentage of Green Talents in their ranks, these results shows that their effort to acquire the necessary amount of skills and knowledge is still ongoing, as is their transition towards more sustainable practices (LinkedIn 2022; Sern, Zaime, and Foong 2018; Hamzeh et al. 2019). Similarly, the Corporate services sector also emerges as a highly recruiting one despite its leading role as employer of Green Talents. This is not surprising, as consulting services often lead the way in new trends, and they may be doing the same today with green professionals. Indeed, considering the scarcity of available Talents, consulting organizations may maximize their availability in the ecosystem by lending them where most needed (Kanda et al. 2018; Stam and van de Ven 2021; LinkedIn 2022).

While these results are certainly encouraging, it is discomforting to see that they confirm the limited attention to Green Talents of key industries for the transition to sustainability, and particularly of Finance and banking, Legal services, and Technology (LinkedIn 2022). This is particularly problematic in EEs, where sustainable new technologies are expected to be developed (Kivimaa et al. 2021; Neumeyer et al. 2021), and where financial and legal actors must provide fundamental services to support enterprises in this transition (Stam and van de Ven 2021; Vona et al. 2018).

Third, these results are confirmed by the analysis of job functions, as Manufacturing, Analytical, and Business ones lead the way also when industry and locations are considered. This shows the primarily technical and analytical nature of sustainability-related professions today (ESCO 2022; McGrath and Powell 2016). Nonetheless, relatively high values of creative jobs show that humanist or social skills may also be fundamental in this process and at many levels, possibly to communicate internally or externally with stakeholders, as much as to expand the concept of sustainability beyond mere environmental variables to include also social and cultural dimensions (Cottafava and Corazza 2021; Zhang and Zeng 2022). Accordingly, these results confirm the validity of the first hypothesis:

- *H1. Employer-specific factors influence the demand for Green Talents*

Fourth, EE variables display solely a limited, though statistically significant, influence on the demand for Green Talents: while the positive influence of Knowledge, Funding, and Focus on Green OJVs was expected (Stam and van de Ven 2021), it is harder to explain the negative effect of Talent availability and Performance. Concerning the first, one possible explanation may be that when the talent pool expands there is less competition to recruit workers within that pool, and hence less OJVs are published (Morel-Curran 2008; Vona et al. 2018). Similarly, particularly high values of Performance (such as in the case of these top-tier ecosystems) may indicate that a specific EE has already acquired sufficient (Green) Talents, thus reducing the demand for new ones. If this was the case, it may suggest that negative feedback in EEs may limit their talent absorption just as they moderate other processes (Sun et al. 2019; Carayannis et al. 2018). In both cases, further research is necessary and additional data on a larger and more diverse number of EEs must be provided before reaching a conclusion. Nonetheless, these results confirm the validity of the second hypothesis:

- *H2. Local EE factors influence the demand for Green Talents*

Conclusion

This paper contributes to the study of entrepreneurial ecosystems (EEs) and their transition to sustainability by investigating their demand for Green Talents as a fundamental resource and an enabling factor for this shift (Stam and van de Ven 2021; Theodoraki, Dana, and Caputo 2022). Scholars have previously employed the concept of EEs to account for the contextual, evolutionary, and nonlinear features of entrepreneurship in countries, regions, and cities (Cavallo, Ghezzi, and Balocco 2019; Feld 2020). There, the relevance of Talents as a one of the fundamental sources for growth and innovation is well recognized. Moreover, recruiting Talents is crucial to acquire new knowledge and skills previously not possessed, and specifically when attempting major transitions in processes and rationales. One such example is the transition to more sustainable practices, for which individual businesses and EEs alike need to recruit Green Talents (Pelinescu 2015; Lovaglio et al. 2018). However, despite the importance of the demand for Green Talents to understand this transition, no research has been yet produced at the level of city EEs.

To fill this gap, the present paper committed to assess the demand for Green Talents in city EEs, explore recurring patterns, and identify potential predicting factors. Drawing on the Quadruple/Quintuple Helix Framework, on multiple streams in economics and management, (Carayannis et al. 2018; Cavallo, Ghezzi, and Balocco 2019), and on Startup Genome 2022 List of EEs, this work identified 20 EEs hosting the most advanced communities of entrepreneurs in the world. Then, from these ecosystems it collected almost 3.5 million OJVs published in the month of November 2022, and quantitatively analyzed them with statistical techniques (Lovaglio et al. 2018; OECD and CEDEFOP 2014).

The preliminary analyses revealed that only 1.53% of all OJVs were aimed at Green Talents, but interesting patterns could be observed: they confirmed that employer-specific factors (thus validating H1) as well as EE-specific factors (thus validating H2) significantly influence the demand for Green Talents. Specifically, Construction, Mining and oil, and Utilities, and Corporate services were confirmed to be in the first line to acquire these talents, while Finance and banking, Technology, and Legal were found to be lagging behind (LinkedIn 2022; Sern, Zaime, and Foong 2018). Moreover, the demand for Green Talents results higher for Manufacturing, Analytical, and Business jobs than to other types, coherent with the relevance of technical and analytical skills and the leading role played by the heavy sectors (ESCO 2022; Cabral and Lochan Dhar 2019). Additionally, local EE factors appear to influence the demand for Green Talents via OJVs, whether negatively such as EE Performance and green Talent availability, or positively such as availability of green Knowledge, Funding, or EE Focus on green enterprises. These results are only partially aligned with the literature on ecosystems, which would primarily expect positive relations to manifest (Stam and van de Ven 2021; Carayannis et al. 2018). Further research is necessary to fully understand the motives of these negative influences.

Though this paper could leverage almost 3.5 million OJVs, of which more than 50,000 directed to Green Talents, dependence on a single source of data significantly limits the validity of this research. Similarly, Startup Genome Cleantech report is a valuable and accurate source of information on EEs and startups but provided already aggregated data that were not originally intended for this purpose. Accordingly, integrating additional data sources, including data on already employed personnel with green skills and traditional data sources on talents, would certainly strengthen these results and constitute the next step of this work.

Nonetheless, these analyses already contribute to the literature with first empirical results on the demand for Green Talents in EEs and confirm existing theories on ecosystem entrepreneurship at the city level. Moreover, they highlight the importance of employer-specific and EE-specific factors, despite hinting at previously undetected negative feedback in EEs. Being crucial for the growth of ecosystems and their transition to sustainability, further research is certainly necessary to investigate them (Carayannis et al. 2018; Theodoraki, Dana, and Caputo 2022). These results also contribute to informing key actors, and namely businesses, universities, and governments, in city ecosystems. They provide first insights on the current demand for Green Talents, which may be further used to explore future scenarios in the prosecution of this work. Specifically this data could be used for benchmarking between cities and sectors (Startup Genome 2022a) and to support data-driven policies for the acquisition of Green Talents, the launch of new subsidiaries, or the design of synergetic training and industrial programs (Hausmann et al. 2014; Carayannis et al. 2018; Del Giudice, Carayannis, and Maggioni 2017). Indeed, previous research has shown that bottom-up approaches underpinned by local ecosystems could be crucial to complement governmental top-down policies and meet the SDGs (Cillo et al. 2020; Palumbo et al. 2021; Cavalli, Polin, and Spinazzola 2022). To achieve this, EEs and organizations within them need to acquire additional and specific resources, including by attracting and employing workers with adequate knowledge and skills (Stam and van de Ven 2021; Pelinescu 2015). By shedding light on the demand for Green Talents in 20 leading city EEs, this work aims to support their transition (Theodoraki, Dana, and Caputo 2022; Carayannis et al. 2018).

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