Research Policy 52 (2023) 104675

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

From hackers to start-ups: Innovation commons and local entrepreneurial activity

Alexander Cuntz [a,*], Jan Peuckert [b]

[a] World Intellectual Property Organization, 34, Chemin des Colombettes, 1211 Geneva 20, Switzerland[1]

[b] Institute for Ecological Economy Research, Potsdamer Str. 105, 10785 Berlin, Germany

ARTICLE INFO

JEL classification:
O30
018
R11
J24

Keywords:
Communities of practice
Innovation commons
Hackerspaces
Entrepreneurship
Digital economy

ABSTRACT

In hacker communities, tech-savvy pioneers collect and share information on nascent technologies. The pool of information shared among users reduces uncertainty about digital technology, but, first and foremost, it reveals entrepreneurial opportunities to users in the community, which is a central tenet of innovation commons theory. In this paper, we are first to explore the role of local hackerspaces for digital entrepreneurship in German counties using cross-sectional time series data. We find that longer-lasting hackerspaces are strongly correlated with the level of digital entrepreneurship in regions, particularly in agglomerations and urban contexts.

1. Motivation

Hackerspaces are "community-operated physical places, where people share their interest in tinkering with technology, meet and work on their projects, and learn from each other" (Hackerspace.org, 2021). This definition encompasses a variety of third places of similar nature in terms of their characteristics and external features (van Holm, 2014), such as hacklabs (Maxigas, 2012), makerspaces (Smith et al., 2013; Hatch, 2014; van Holm, 2017), and fablabs (Gershenfeld, 2005; Walter-Herrmann and Büching, 2013). Hackerspaces bring together communities of tech-savvy users around the use of nascent technologies, "engaging them in collective action and developing rules to generate, share and govern innovation resources" (Cohendet et al., 2021, p. 2). A growing number of hackerspaces have been founded worldwide (Guimarães Pereira et al., 2017) and there is an ongoing debate about their economic significance (Anderson, 2012; Williams and Hall, 2015; van Holm, 2017; Svensson and Hartmann, 2018; Boutillier et al., 2020), in particular with regard to their impact on entrepreneurship (Mortara and Parisot, 2016). The relevance of hackerspaces for innovation and regional development is supported by anecdotes from Silicon Valley, where many successful entrepreneurs were born out of hackerspace environments.[2]

In this paper, we explore the importance of hackerspaces as components of local ecosystems for digital entrepreneurship. We focus on digital start-ups because the digital sector has been characterized by many nascent technology developments over the last 20 years and is an area of great interest for hacker communities. We empirically investigate how the local existence of a hackerspace relates to the actual number of new ICT firms created in a region.

So far, most empirical research on hackerspaces has taken a more qualitative approach and does not systematically assess economic impact (Smith, 2017). One notable exception is Halbinger (2018), surveying individual users in makerspaces. She finds that the share of innovators and the number of users also commercializing ideas is substantially higher than what could be expected based on their skills and motivation before joining the hackerspace. Hence, spaces not only attract people who are interested in innovation and business creation upfront, but also enhance the ability of any user to develop new commercial ideas in longer term. She attributes the effect to the easy and inexpensive access to tools, training and collaborators within spaces

* Corresponding author.
E-mail addresses: alexander.cuntz@wipo.int (A. Cuntz), jan.peuckert@ioew.de (J. Peuckert).

[1] The views expressed are those of the authors, and do not necessarily reflect the views of the World Intellectual Property Organization or its member states.

[2] For example, Steve Wozniak was an active member of the Homebrew Computer Club, a computer hobbyist group and do-it-yourself hackerspace resident in Menlo Park, California. He shared all his designs for the Apple I computer within this community, before he and Steve Jobs founded Apple Computer (Freiberger and Swaine, 1999).

https://doi.org/10.1016/j.respol.2022.104675
Received 30 June 2020; Received in revised form 27 September 2022; Accepted 15 November 2022
Available online 2 December 2022

as well as the localized information spillovers from the community of hackers.

The previous research ascribes the impact of hackerspaces on local entrepreneurship and regional development mostly to the provisioning of technical knowledge and shared production capacities, being a valuable service for aspiring entrepreneurs (Mortara and Parisot, 2016; van Holm, 2017; Browder et al., 2019). A recent conceptual approach (Potts, 2019; Allen and Potts, 2016a,b), however, points to the commons-based governance structures of hackerspaces as the core mechanism enabling the discovery of new entrepreneurial opportunities at nascent technology stages and where markets do not yet exist. According to this new theory, hackerspaces are prime examples of innovation commons (Allen, 2017), and they provide for an institutional solution to overcome collective action problems involving innovation. The “fierce culture of sharing” and the implicit understanding that “to participate you had to contribute” makes access to these places valuable for their members (Potts, 2019, p. 18). This collaborative setting helps the community to accumulate “information about the innovation”, which “enables people to overcome the uncertainty about the nature of the market opportunity, and thus to become entrepreneurs” (Potts, 2019, p. 39).[3]

We extend the existing research on hackerspaces in several important directions. First, we are first to quantitatively assess the association between the existence of a hackerspace and local firm formation using extensive panel data. For that purpose, we track the historical emergence of the hacker movement in Germany and the establishment of hackerspaces over time. Fig. 1 shows the geographical distribution of hackerspaces across German counties, indicating the first hackerspace establishment.[4] While the research design does not allow for causal inference, we find that hackerspace establishment is positively correlated with digital start-up formation in regions. In light of the existing literature on hackerspaces, our empirical findings showcase the important role of hackerspaces for new firm formation and underline their regional relevance as elements of digital innovation ecosystems.

Second, our research contributes to the growing literature on regional entrepreneurship. This literature identifies key determinants of regional performance in entrepreneurial ecosystems (Isenberg, 2010; Acs et al., 2017, 2014). With our focus on hackerspaces as a new and informal type of supporting infrastructure in a given place, we can add another important explanatory factor. What makes them particular is their role as a facilitator open to all tech-affine users and conducive to the collective discovery process of entrepreneurial opportunities in user communities. Hackerspaces support and grow the pool of so-called ‘proto-entrepreneurs’ (Potts, 2019) in a region, they provide a point of entry for an alternative set of agents (Cohendet et al., 2018), and they can be a source of complementary user information on nascent technology, so far little or not explored in the literature on entrepreneurial ecosystems (Audretsch et al., 2017). For agglomerations and urban contexts in particular, we find that, all other things being equal, the longer hackerspaces exist in regions, the higher is the level of digital entrepreneurship. Hackerspace existence is thus another important factor that helps explain regional differences in start-up intensities.

Third, our research findings can be interpreted as supporting evidence for the theory of innovation commons (Potts, 2019). As argued above, this theory predicts that, at early stages of technological development, commons-based governance structures can help prepare the emergence of markets and entrepreneurs. From this perspective, the self-imposed rules of hackerspace communities ultimately serve as an institutional device for collective action, generating information about market opportunities that would otherwise not be available. Consequently, regions with communities in place which routinely harness this *cooperative social technology of alertness* (Potts, 2019, p. 146) will very likely produce more entrepreneurs than regions where entrepreneurial alertness only exists at the individual level. Our main finding that the longevity of hackerspaces significantly correlates with local startup formation is in line with these expectations and very much supports this interpretation of results. Although our analysis is limited to the digital sector and a specific type of grassroots institution, our findings are nevertheless indicative of the basic functioning of innovation commons for entrepreneurial activities. The evidence we provide in this paper is meant to enable further theory development and encourage further empirical work in this emerging field of research.

Fourth, the research has important takeaways for the design of innovation and local development policies. It stresses the need to recognize users as sources of innovation (Bradonjic et al., 2019) and the relevance of informal agents for local knowledge creation (Cohendet et al., 2021). Our findings highlight the potential value of more inclusive policy support to open communities of practice and local entrepreneurial discovery at very early stages of technology development.[5] These new forms of support and co-location tools would target the alternative set of agents attracted by hackerspaces and similar bottom-up facilities. This would clearly go beyond the funding and support granted to established organizations conducting research and investing in innovation in a location (local firms, universities, IP rights etc.). Arguably, these new policy tools cannot build on standard eligibility criteria and funding logic based on merits and reputation. Rather, cautious and low-scale policy experimentation is required towards communities that does not run the risk of redirecting community practices and interest, and avoids damaging their self-governance and general openness to local users. Moreover, in light of our findings, (temporary) support would need to last for several years for its longer-term impact to unfold and, once again, it should target preparatory and nascent stages of technology development. In this way, it will also pre-date and distinguish from other types of services such as incubators and accelerators mainly targeting aspiring entrepreneurs with a fixed commercial idea ex ante and ventures build around more mature technologies (Cohendet et al., 2001; Rothaermel and Thursby, 2005).

The paper is structured as follows. Section 2 briefly reviews the related literature on innovation commons, user entrepreneurship in communities and regional determinants of new firm formation. Sections 3 and 4 describe the data and outline the exploratory approach. Sections 5 and 6 present main findings and discuss policy implications. Section 7 concludes.

[3] This sharing of tacit and individual-level information on tech applications and immediate user needs is reciprocal, and it is governed by rules laid out in the commons. By ’allowing or compelling free and full inspection by all’, this can bring potential new applications to light (Potts et al., 2021), with the different lenses users in spaces bring to the task. Notably, the complementary information initially shared and assembled in spaces is not geared towards commercial application and, at that point in time, cannot follow a systematic research process with clearly defined goals. Rather, in such a collaborative environment open to play and hobbyism, information sharing and user access to spaces is not constrained or filtered, as sharing takes place at a point in time when relatively little is known on the commercial value of information and potential uses of technology. Once sufficient complementary information is pooled in the commons and is actively shared among members, only then a preliminary market valuation of technological applications is feasible, and new commercial opportunities may become evident, turning (some) users into entrepreneurs.

[4] Hacker culture is well developed in Germany. In the wake of a political congress in West-Berlin, most prominently, the Chaos Computer Club (CCC) was founded in 1981. From then onwards, the CCC was organized in regional ‘chapters’ that set up reoccurring events and hacker meetings, establishing the first open-membership hackerspaces locally. Following the example and design patterns of CCC venues, hackerspaces began to spread across Germany at the turn of the century and growth accelerated after 2007. Today, the CCC is the largest hacker organization in Europe, with its more than 8000 members and thirty sub-regional associations.

[5] Hackerspaces as grassroots initiatives among users are open to everyone interested in tech use and application, including mere play and hobbyism, and having an idea on entrepreneurial opportunity and the commercial value of a new venture ex ante is not a requirement to become a hackerspace member and sharing information within the space.

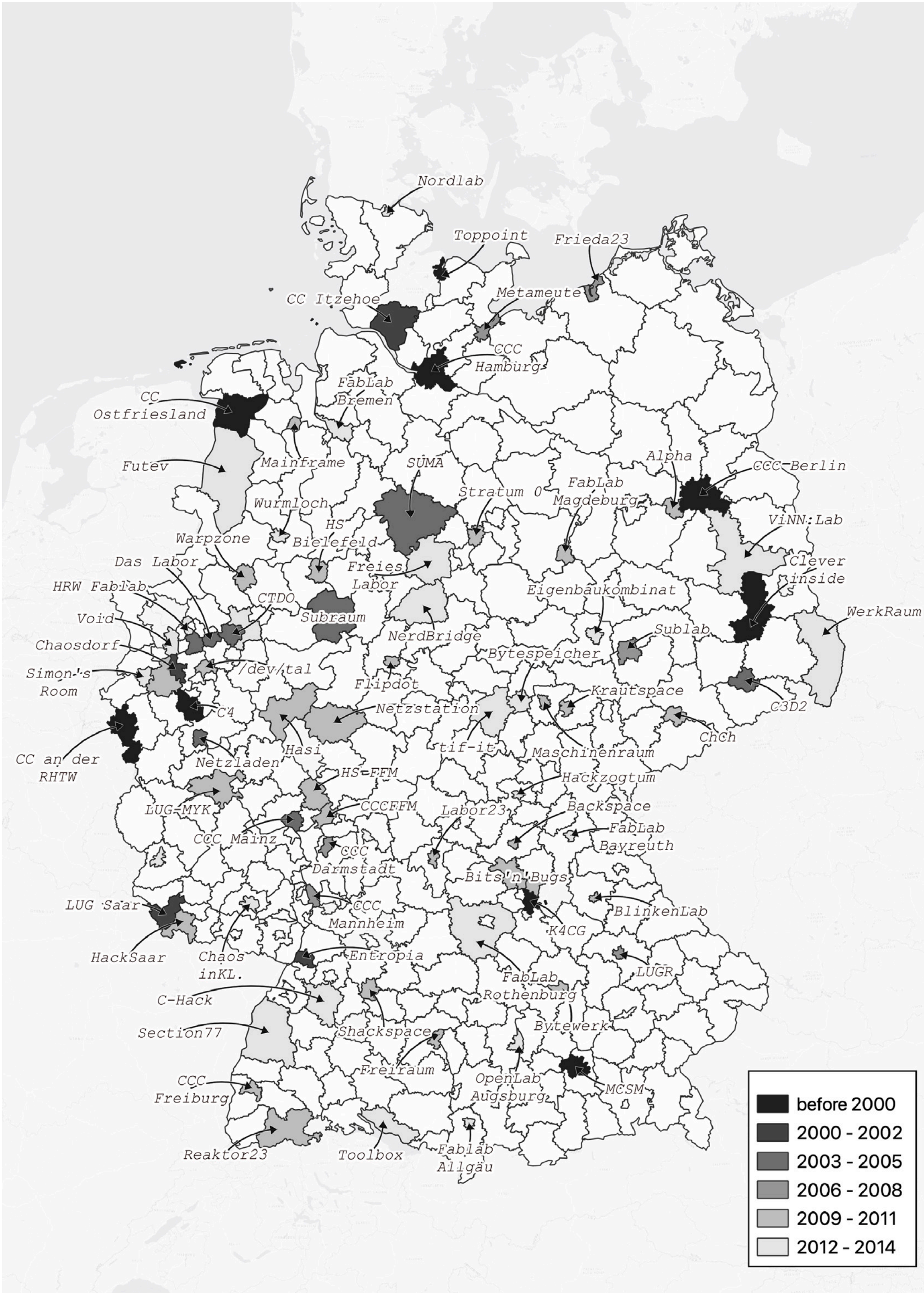

Fig. 1. Geographical distribution of the emergence of hackerspaces across Germany over time showing the name of the first hackerspace established in a given county. *Sources for base map:* Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

2. Related literature

2.1. Community entrepreneurship and innovation commons theory

Different to the traditional producer- or firm-centric model of innovation, users are an important source of innovation ('user' innovation or 'free' innovation). Users frequently modify existing products, or create entirely new solutions in response to their non-standard, heterogeneous needs (von Hippel, 1986, 2005, 2017). In many instances, self-interest rewards users and helps them recover private development costs (von Hippel, 2017). User communities typically either focus on a common interest theme, or on one or more products of a particular manufacturer (for examples, see Schulz and Wagner, 2008; Wenger, 2004). In addition, communities also provide for sociability, support, a sense of belonging, and social identity among their users (Wellman et al., 2002; von Hippel, 2007). Given that users are endowed with first-hand information on latent user preferences for design and functionality as well as they have exclusive information on individual use experiences, user innovators often pioneer and foreshadow new emerging markets (Thomke and von Hippel, 2002). Frequently, user development efforts are widely distributed in communities of practice and user innovations are freely shared with others (on 'free revealing', see, for example, Franke and Shah, 2003). In this way, communities enable user innovators to combine and leverage efforts, and communities help the diffusion of user innovations (von Hippel and Paradiso, 2008).

Notably, users exchanging knowledge in communities of practice can also develop entrepreneurial aspirations and start to exploit community-based innovations commercially (Ferdinand, 2017). In this way, user experimentation is not limited to product development and innovation, but sometimes extends to the formation of new firms. 'User entrepreneurs' or 'accidental entrepreneurs' are often inspired by their own needs (Agarwal-Tronetti and Shah, 2014; Shah and Tripsas, 2016). User-founded firms have limited access to complementary resources such as (mass) manufacturing and distribution capabilities as practices in communities often centre on creation and use. Still, when compared to other non-user entrepreneurs, their unique asset is the exclusive access to and shared resources within the community (for example, Shah and Mody, 2014). User entrepreneurs benefit from communities because other users provide collective feedback and important "information regarding the value proposition or existence of a potential entrepreneurial opportunity" is shared at low search costs (Agarwal-Tronetti and Shah, 2014, p. 21). Moreover, communities create an immediate demand for new commercial solutions and provide a potential market for user entrepreneurs.

While, from a user's perspective, technological knowledge is non-rivalrous, information on entrepreneurial opportunities is rivalrous from the perspective of aspiring entrepreneurs in communities. As competition reduces the prospective payoffs of entrepreneurial action, mutual revelation of such information may be subject to free-riding. As Potts (2019) explains, the innovation commons solves this social dilemma by providing a 'two-commons solution': The primary commons, consisting of innovation resources and technology, serves as a screening mechanism for the secondary commons, which contain the information that unlocks the entrepreneurial opportunity. Functioning as a focal point and defining the rules of reciprocity, the innovation commons solves both the coordination and the collective action problem.[6]

In this way, innovation commons structures can provide an alternative, governance-based explanation for the emergence and sustained collaboration and information sharing in local hackerspace communities. While membership is open, community recognition is contingent upon the willingness of users to mutually share experiences and learn skills. Cooperation is based on the exchange of private information where contributors self-identify as knowledgeable experts (Langlois and Garzarelli, 2008). Individual users contribute knowledge because they expect others to do so as well. The group's ability to work together and pool information provides a competitive advantage over non-cooperative individual entrepreneurs in evaluating new technological and commercial opportunities. Arguably, this governance structure adds another dimension to the standard notion in the literature, which focuses on individual determinants of creativity and community participation such as intrinsic motivation, peer recognition and social preferences of the individual to explain economic behaviour (Amabile, 1988; Frey and Oberholzer-Gee, 1997; Bénabou and Tirole, 2006).

Regional ecosystems for aspiring entrepreneurs can benefit from the existence of hackerspaces. This is because they serve as a local infrastructure for the pooling of dispersed and granular information and, importantly, the collective discovery of entrepreneurial opportunity. In this way, innovation commons such as hackerspaces complement market mechanisms for the discovery of entrepreneurial opportunities at the individual level. In accordance with Potts (2019), local commons may be understood as a *cooperative social technology of alertness* complementing individual-level alertness and competition in markets. In line with Allen and Potts (2016b), higher incidences of user entrepreneurship can be observed at early stages of the industry life cycle (Baldwin et al., 2006; Shah and Tripsas, 2016). Early stages of technologies tend to coincide with weaker appropriability regimes and, potentially, lower barriers to entry for user entrepreneurs. User-founded firms are thus often more prevalent in yet unserved markets and nascent industries, as was the case for IT industries and the many user communities emerging around new digital technologies (at the time).

Moreover, from an economic geography perspective, there is a growing literature looking at the spatial dynamics of user innovation and user communities. However, this mostly qualitative research is often based on case studies or cluster-level analysis (Cohendet et al., 2018; Kostakis et al., 2015, for example). From that perspective, hackerspace communities can be described as a 'middleground' element in the formation of local industry and a local infrastructure for innovation. Here, the main function of the middleground is to link up knowledge production of the informal underground with the formal exploitation of organizations and institutions on the 'upperground', including local entrepreneurs (Lange and Schüßler, 2018; Cohendet et al., 2018).[7] Notably, the concept of the middleground also requires physical presence for people to meet, share their experience or participate in collective events (Grandadam et al., 2013). In this way, our exploratory study also provides first-hand evidence on the impact of middleground activities in hacker communities on regional firm formation.

2.2. Other determinants of regional firm foundation

Entrepreneurial ecosystems provide a systemic view of entrepreneurship and entrepreneurship is considered as the conditional output of the (eco)system (Isenberg, 2010). The original concept can be traced back to the literature on regional development and strategy (Acs et al., 2017). Ultimately, ecosystems allocate resources that build on individual-level opportunity pursuit through the creation of new ventures, whose activity and outcomes are regulated and mediated by region-specific institutions and characteristics which we address in the following (Acs et al., 2014).

Another determinant is the spatial division of labour across places and the industry structure in a given region. So, for example, locations with branch establishments and production plants typically see lower rates of entrepreneurship and innovation than places hosting research and development (R&D) facilities (Watts, 1981). This is because workers in such regions are less exposed to innovation happening locally and they may also have lower skill levels. At the same time, regions that have many independently and locally operating firms rather than branches reporting to headquarter outside the region, seem to benefit from spillovers between local firms. Ultimately, they provide a more fertile ground for innovation and spin-offs from firms in the region (Malecki, 1991).

[6] Without necessarily knowing who else has relevant information, potential user entrepreneurs "can nevertheless coordinate on meeting in the innovation commons in the expectation of mutual sharing of information" (Potts, 2019, :97). Since users act without knowing the value of their own or others' privately held information, they can rationally agree upon a set of rules that gives them equal access to collective outcomes. Cooperation arises because everyone expects everyone else to adhere to the social norms established in the commons.

[7] Moreover, an active middleground translates and confronts local ideas with knowledge and practices issued from different parts of the world. According to this view, hackerspaces are necessary to nurture on the middleground and also help strengthen 'global pipelines' (Storper and Venables, 2004).

Moreover, sectoral bias plays an important role. So, the regional focus on specific technologies and industries generates different levels of entrepreneurial opportunities in the first place (Cooper and Gimeno-Gascon, 1990). And, there is often a reinforcing mechanism that makes new firms more likely to emerge in the same incumbent sectors (Malecki, 1991). The same applies to industrial specialization and regions with many small firms that typically see more local entrepreneurship (Moyes and Westhead, 1990). In similar vein and related to the focus of our paper, in regions where service firms dominate industry structure this provide more opportunities for entrepreneurship (Acs et al., 2008). Finally, when industry structures are underdeveloped in a region and regular employment opportunities are scarce, the level of local 'necessity' entrepreneurs can be higher which may add to overall regional performance (Fairlie and Fossen, 2019). More broadly, corporate decisions to locate in a specific region also affect the set of occupational choices and the competition for local talent over wages. In turn, this likely changes the relative attractiveness of entrepreneurial careers locally and the regional persistence of entrepreneurial culture in the long-term (Stuetzer et al., 2016).

The stock of local knowledge and technical skills embodied in human capital as well as the talent exchanges across regions are other important drivers of local entrepreneurship. This is because they provide resources and generate local spillovers (Acs et al., 2002). So, for example, higher education and research institutions not only provide for new graduates enlarging the local talent pool that firms and founders can recruit from (Qian et al., 2012; Feldman and Audretsch, 1999; Bonander et al., 2016). Next to the knowledge accumulated in local firms, public and private research institutions and universities are another locus in regions where research is conducted. This can generate knowledge spillovers and lead to new academic spin-offs in the region (Qian, 2010). More generally, tacit and codified sources of knowledge and information are enabling local innovation and entrepreneurs (Furman et al., 2018). Some of this knowledge is codified and disclosed in patent documents and other IP rights granted to local applicants. Beyond that, inward mobility of talent from outside the region and the associated inflow of new ideas and skills further enhance local innovation and firm formation (Schäfer and Henn, 2018).

These findings have triggered researchers to look more closely at the ability of regions to attract mobile talent from outside and the role of cultural and other amenities of places for potential entrepreneurs. For example, local creators and artistic communities seem to help attract mobile entrepreneurs and retain high-skilled talent within a region (Falck et al., 2011). Other research emphasizes the role of local 'subculture' or 'bohemian' communities for regional entrepreneurship, mainly because this promotes cultural diversity in places (Audretsch et al., 2017; Cohendet et al., 2018). Moreover, some regions provide better access to high-quality, physical infrastructures (e.g. transport, communication, public services) in place to attract entrepreneurial and other talent from outside. However, it is also the 'social capital' and 'institutional thickness' within a region that may further encourages firm formation (Amin and Thrift, 1995; Putnam, 1993). Socio-demographic structures such as age distribution also matter for local activity levels (Lewis and Massey, 2018). For example, stylized facts there suggest that entrepreneurship is less common among younger parts of the population. However, in the context of our paper and its focus on digital start-ups, there is some reasons to believe that younger persons were among early adopters of digital technologies and that they would chose new business models in sectors where entry barriers and capital requirements are relatively lower for regional entrepreneurship (Shane, 2008).

Related to the last point, there is robust evidence that entrepreneurship also depends on local access to finance and funding (Dorsey, 1979; Davis and Stetson, 1984). Access to finance will impact the ability of new entrepreneurs to sustain and grow their businesses (Cassar, 2004), because they are often exposed to incomplete appropriability of the returns of early-stage R&D and initially face large technological and market uncertainty. In addition, when an entrepreneur cannot provide all necessary funds from private assets (Evans and Jovanovic, 1989), external financing will be required which is subject to information asymmetries between local entrepreneurs and venture capital providers (Carpenter and Petersen, 2002). One way to overcome this issue is for technology start-ups' ability to signal quality (Bester, 1985). In addition, their ability to provide collateral is typically limited, as much of their assets are intangible and may be company-specific (Elitzur and Gavious, 2003). This will also apply to new digital firms that form locally.

This paper extends the existing literature on hackerspaces and determinants of regional entrepreneurship in several important ways. First, this research takes a more ambitious quantitative approach to assess the impact of hackerspaces on regional performance. Hence, it provides for a data-based perspective on hackerspaces and local communities of practice in an area where so far research is particularly scarce or research is mostly based on case studies. Second, our research is a first exploratory study on hackerspaces as a particular case and prime example of innovation commons structures and impact. We hope this research can spur further empirical work in this area and it will help further develop and validate innovation commons theory in the light of our findings. Third, with the focus on hackerspaces and regions, the approach taken in this paper highlights the role of open and informal support facilities in entrepreneurial ecosystems. Hence, we can add another important explanatory factor to the literature that determines local firm formation. In the next section, we introduce the data collected for analysis.

3. Data

We compile a large county-level panel data set covering a total period of 13 years, from 2001 to 2014. For each of the 400 German counties, we can observe the total annual number of digital start-ups and, if applicable, the year of the first hackerspace foundation. Moreover, our data includes several important regional characteristics, for example, the presence of a higher education institution or the total number of ICT patents in a given county and year. These measure are meant to approximate selected regional determinants of new firm formation as identified in the previous section.

The data comes from five main sources. As the main link to match data from different sources, we use the NUTS geocoding standard. If not stated differently, the data is collected on county-level (NUTS3,"Kreis") and matched via that classification.[8] In order to assign hackerspaces to NUTS3 districts, we use the postal code of the hackerspace address with the correspondence table provided by Eurostat.[9] Table 9 in the Annex provides summary statistics of all relevant variables and estimation samples used in the following sections.

First, we deploy data from ORBIS-Bureau van Dijk on new firm formation, a database recording new entries in official corporate registry files. A set of standard industry classification codes allows us to filter and identify digital start-ups among all newly registered entities (for the specific industry classification used, please refer to Table 8 in the Annex). This part of the data builds on previous data collection and research by Mueller et al. (2016), Mueller et al. (2017) and EFI (2016), which maps entrepreneurial activity and market capitalization in these sectors. In this way, a large fraction of the new ventures' services and products in digital sectors relies on nascent digital technologies and thus many of the start-ups in our sample can be considered innovative or, at least, can be considered early adopters of digital technology. We further note that entrepreneurial activity – as measured by the annual number of start-ups per civilian labour force – is substantially lower

8 Most of the statistics were available at the district level (NUTS3), with a few exceptions indicated in the text.

9 https://gisco-services.ec.europa.eu/tercet/flat-files, v2.3 2013.

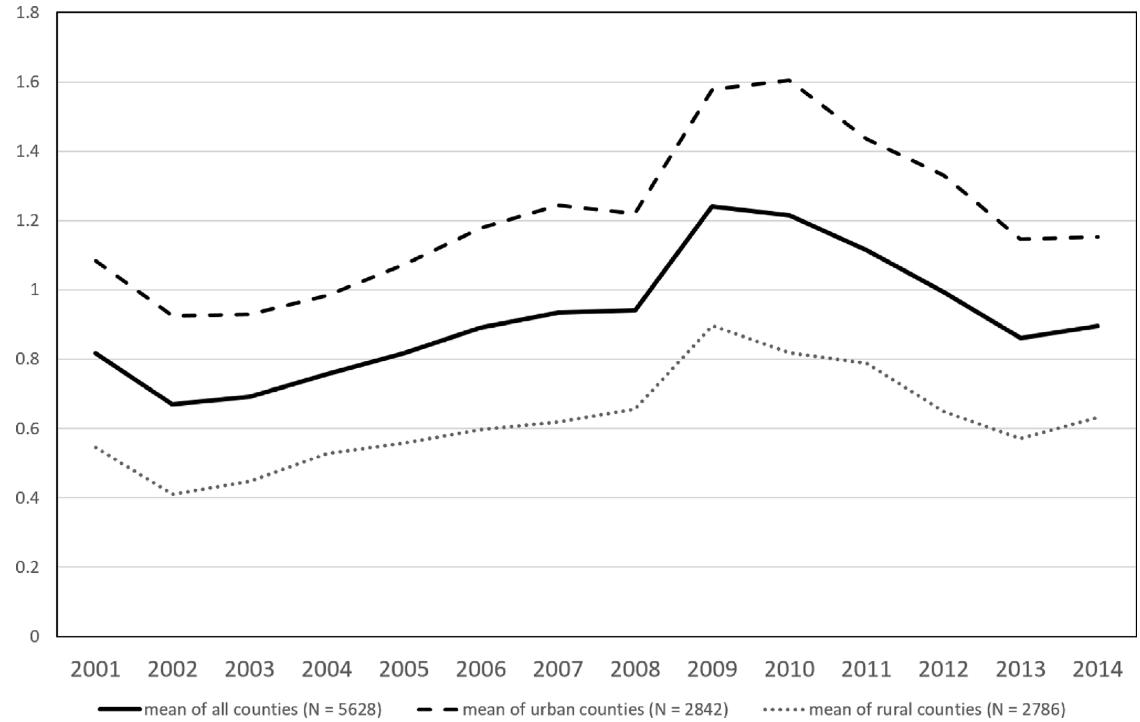

Fig. 2. Mean digital start-up rates (number of start-ups per 10,000 worker),2001–2014, by type of county.

in rural counties with an average of 0.6 digital start-ups per 10,000 workers than in urban areas with an average rate of 1.2 digital start-ups in the observation period, when distinguishing rural and urban areas based on information on structural types of regions ('siedlungsstruktureller Kreistyp') provided in the INKAR database.[10] Fig. 2 illustrates this.

Second, we collect novel data on the year of first establishment and geolocation of hackerspaces from a dedicated website www.hackerspaces.org. The public website invites hackerspaces across Europe to register and self-report information.[11] Most hackerspaces in our data sample have a similar organizational structure and history, as hackerspaces are typically founded by a few creative artists and tech-savvy enthusiasts in the region. This, in turn, means that hackerspaces are not randomly assigned to regions, but that a sufficiently large population of aspiring technologists and entrepreneurs must be present in the area, as a precondition for spaces to emerge. Notably, spaces are developed and operated using specific 'Hackerspace Design Patterns' templates and governance models. These templates are publicly advertised by the Chaos Computer Club and provide best practices and decision criteria for the establishment of new hackerspaces in a region.[12] We triangulate the available information on hackerspaces using alternative data sources. In this way, we can make sure that coverage of hackerspaces located in Germany is close to complete. For instance, we compare our initial data to public lists of local hangouts provided by the CCC[13] and data records for German FabLab member institutions,[14] as well as registered makerspaces under the German Association of Community Workshops (VOW)[15]. Because of inconsistencies and sometimes outdated information in our initial data, we do not include the more granular information on hackerspace characteristics available on www.hackerspaces.org, such as the number of members, the size of rooms or the membership fees charged to members in the hackerspace. At large, we are able to identify a total sample of 162 hackerspaces across all German counties. Of these hackerspaces, 137 were founded before the end of 2014 (Fig. 3). During our observation period, 20 percent of all German regions had at least one hackerspace already established.

Third, we gather systematic data from EUROSTAT on aggregate numbers of ICT patent applications to the European Patent Office (EPO) by priority year. Patent applications are geocoded and linked to specific counties based on inventors' addresses recorded on the application. EUROSTAT identifies patent applications in four main fields related to ICT via a standard set of international patent classification (IPC) subclasses. These fields include telecommunications, consumer electronics, computers, office machinery and other ICT technology.[16] We create a stock variable that accumulates all ICT patent applications of local inventors since 1995. This regional patenting indicator approximates the stock of codified and formally protected knowledge and ICT-related (technological) innovation available in a given county.

Fourth, we build an indicator of 'creative classes' by exploiting annual records from a unique social insurance scheme supporting

[10] We last accessed and downloaded the database run by the German Federal Statistical Office, on January 1, 2018.

[11] Data was accessed and downloaded on January 1, 2017. Where information on first establishment and geolocation is missing, we manually fill this based on the information provided on individual websites of hackerspaces and social media profiles.

[12] A specification of the design patterns can be accessed here.

[13] https://www.ccc.de/en/regional

[14] https://www.fablabs.io/labs?country=DE

[15] https://www.offene-werkstaetten.org/werkstaetten

[16] IPC codes in the field of telecommunications include G01S, G08C, G09C, H01P, H01Q, H01S3/(025, 043, 063, 067, 085, 0933, 0941, 103, 133, 18, 19, 25), H1S5, H03B, H03C, H03D, H03H, H03M, H04B, H04J, H04K, H04L, H04M, H04Q; codes in the field of consumer electronics include G11B, H03F, H03G, H03J, H04H, H04N, H04R, H04S; in the field of computers and office machinery B07C, B41J, B41K, G02F, G03G, G05F, G06, G07, G09G, G10L, G11C, H03K, H03L; in the field of other digital technologies this includes G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N, G01P, G01R, G01V, G01 W, G02B6, G05B, G08G, G09B, H01B11, H01J (11/, 13/, 15/, 17/, 19/, 21/, 23/, 25/, 27/, 29/, 31/, 33/, 40/, 41/, 43/, 45/), H01L.

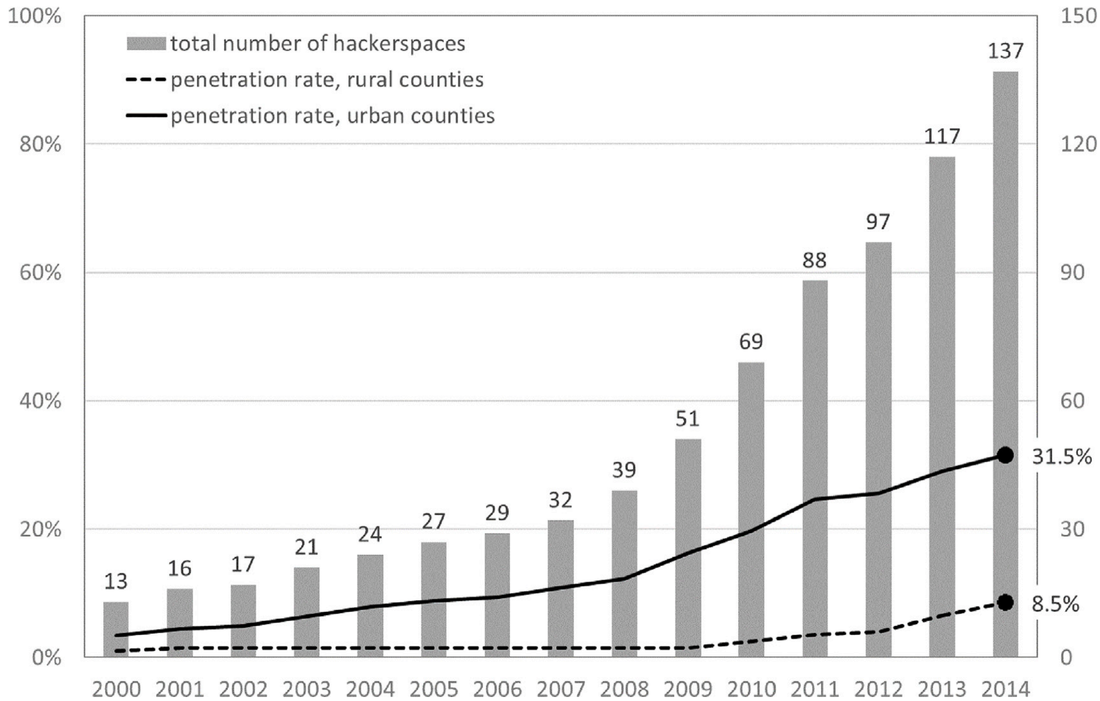

Fig. 3. Aggregate number (right axis), rural and urban penetration rates of hackerspaces (left axis) in Germany,2000–2014.

self-employed artists resident in Germany (the 'Kuenstlersozialversicherungskasse' (KSK)) as in Audretsch et al. (2017). Launched in 1983 and with close to 200,000 artists insured in 2018, the basic idea of the KSK model is to offer self-employed artists an insurance scheme with similar benefits and public co-financing of insurance costs[17] as the public scheme available to those working in regular employment positions where insurance costs are co-financed by employers. Artists self-identify when insuring under the scheme, reporting revenues from self-employed, creative work in order to have access to the benefits of the scheme. Among other things, KSK records thus include the total number of self-employed and insured creators on NUTS-1 ('Laender') levels and across artistic disciplines, such as fine arts, performing arts, music and creative writing.

Fifth, we collect various socio-economic statistics and other regional-level characteristics from the INKAR database. This provides us with time-series data on regional gross domestic product (GDP) per capita, value added, population density, civilian labour force,[18] the share of tertiary sector employment, unemployment rates, the share of young inhabitants,[19] the total number of students, election turnout and the county's inward migration rate ('Zuzugsrate').[20] Most covariates from the INKAR database are determinants of regional entrepreneurship that are well-established in the literature and are more extensively discussed in the previous section. Moreover, we gather time-series data on the presence and establishment of higher education institutions in German counties from the ETER project.[21] Finally, data available on venture capital (VC, gross investment) comes from annual reports of the German Private Equity and Venture Capital Association (BVK 2001–2014). This data is available at NUTS-1 levels only and allows to account for and proxy regional access to venture finance. The next section introduces the empirical approach in this study and describes our baseline model.

4. Empirical strategy

We explore the relationship between hacker communities and entrepreneurial activity by estimating the effect of local framework conditions, including the existence of a hackerspace, on the digital start-up rate in a region. To this aim, we compile a large panel of observations that merges annual counts of digital start-ups with a set of conventional determinants of entrepreneurship, as well as local hackerspace indicators, the factor of interest. Previous research uses a similar research design and econometric set-up (Pfister et al., 2016; Cowan and Zinovyeva, 2013). Descriptive evidence in Fig. 4 already suggests that, on average, digital entrepreneurial activity in a region increases, once a local hackerspace is established. This equally applies to post-periods trends in urban and rural counties. We use a conditional fixed-effects Poisson panel regression[22] to account for the non-negative and discrete nature of start-up counts, and we control for unobserved, time-invariant differences between counties using fixed effects. The civilian labour force (LF) in each county and year is specified as an exposure variable. Thus, the regression model is set up to estimate the effects of hackerspace establishment on the local, digital start-up rate, as measured by the intensity per worker and year.

Moreover, we address treatment selection and omitted variable bias by using a Propensity Score Matching (PSM) approach. As argued before, hackerspaces are not randomly distributed over counties and time, but their establishment is more likely and earlier to occur in counties which do provide better conditions for digital start-ups in the first place, as for instance some counties might be endowed with a larger population of tech-savvy users. In this way, panel estimates might be subject to omitted variables bias, beyond what fixed effects

[17] In order to finance public co-financing taxes are being collected from entities commissioning out and outsourcing work to self-employed creators such as marketing companies, museums, theatres, publishers etc.

[18] The size calculation of the potential of the labour force is based on International Labour Organization concept ("zivile Erwerbspersonen"). It accounts for employed, self-employed and (registered) unemployed work force.

[19] The share accounts for those aged 25 to (below) 30 relative to the total population in the region.

[20] The rate is defined as incoming inhabitants from other counties, Bundeslaender or countries, per 1000 inhabitants.

[21] https://www.eter-project.com

[22] https://www.stata.com/manuals13/xtxtPoisson.pdf

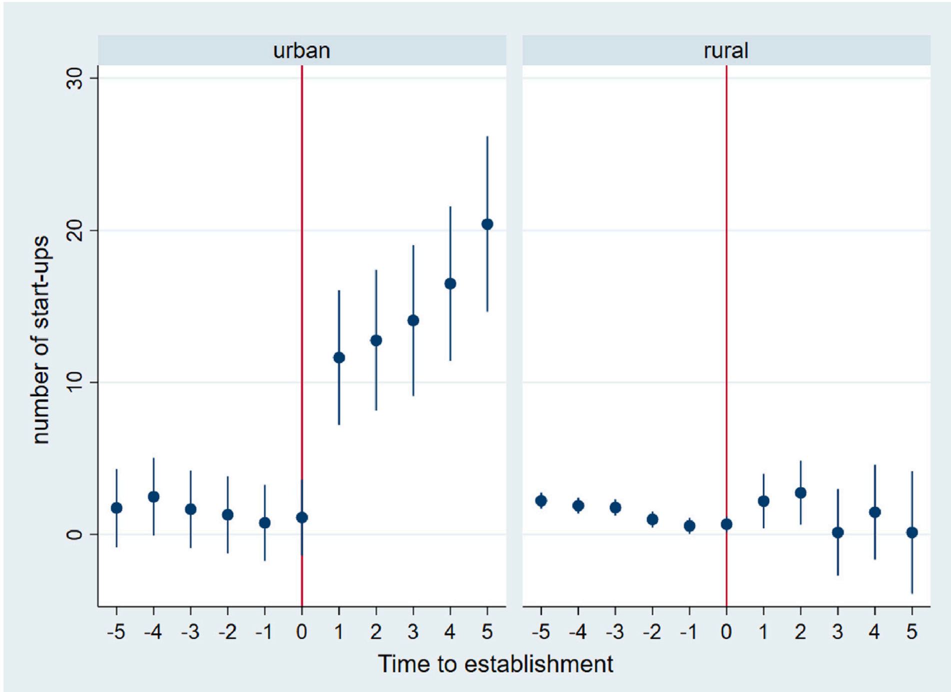

Fig. 4. Coefficient plot for the annual number of ICT start-ups by agglomeration type, 5 years before/after the establishment of a local hackerspace. Sample of urban and rural regions with hackerspaces established after the year 2000.

are able to absorb. PSM is commonly applied to estimate treatment effects, even though it does not provide for a causal effect identification. However, the approach corrects for some of the potential selection bias in the assignment to the treatment (here: the creation of a hackerspaces in predestinated counties). PSM constructs the counterfactual control group based on untreated cases with very similar preconditions and by discarding only observations outside the range of common support. More specifically, we deploy regression (covariance) adjustment techniques where, as a first procedural step, a large set of background covariates is used to estimate the propensity score in a logistic model (Table 6 in the Annex) which also allows for complex interactions and higher order terms (D'Agostino, 1998; King and Nielsen, 2019). Accordingly, the propensity score is the conditional probability of hackerspace existence, given a vector of covariates.[23] As a second step, a subset of these covariates and the propensity score estimates are used in the regression adjustment. Tests confirm that balancing on scores is able to reduce bias for most variables in matched samples (covariate-balance Table 7). Ultimately, the levels of acceptable imbalance will depend on the strength of association between covariate and outcome (Granger et al., 2020). Arguably, stronger predictors of outcome such as the incoming migrants control and the share of young inhabitants contribute more towards confounding bias. This, in turn, suggests that, at large, covariates seem well balanced after the PSM exercise.

4.1. Hackerspace indicators

Arguably, the impact of hackerspaces is indistinguishably linked to the (unobserved) activities of local hacker communities. Our explorative approach is based on an understanding of hackerspaces as 'catalysers' for local activities of hackers and as 'breeders' of the innovation commons. Hackerspaces provide the physical and social infrastructure for the exchange of technical know-how and revealing information on entrepreneurial opportunities by like-minded peers in the neighbourhood. So, there might be an immediate 'treatment effect' from hackerspace establishment. This would allow the local user community to tap into already existing pools of knowledge right away. However, dynamic aspects are also relevant. The impact on local economic activity may only slowly unfold and develop over time with the accumulation of non-proprietary, dispersed knowledge and information within the respective communities. So, the 'infrastructural effect' of hackerspaces is likely to gradually build up as more information on potential applications and entrepreneurial opportunities becomes available and is shared in the hackerspace.

In order to empirically capture the prescribed mechanisms, we construct two alternative indicators of hackerspaces when assessing the impact on entrepreneurial opportunities revealed to users over time (as approximated by start-up rates in regions). The first hackerspace indicator is a simple binary variable that flags the local establishment of a hackerspace in a given year and county. This variable is zero if there is no hackerspace in place, and it takes the value of one for the first and consecutive years after the local hackerspace is established. An alternative hackerspace indicator counts the number of years passed since the establishment of the first hackerspace in the region. This indicator is supposed to better reflect the growing stock of information and entrepreneurial opportunities revealed within the local hacker community. This makes activities in spaces ever more productive and provides a more fertile ground for new firm formation in the region.

4.2. Control variables

We include a series of lagged control variables that also determine the formation of new businesses in a region in order to isolate the

[23] We use the Stata PSCORE package to identify the total number of propensity score intervals (or blocks) it takes until, in all intervals, the treatment (i.e. a local hackerspace is established) and control groups of counties (none established) are comparable in all other dimensions. Counties that cannot be matched are discarded from the analysis sample. We select a large set of covariates that potentially correlate with both the hackerspace probability and the ICT startup rates. The initial set of covariates includes pretreatment, county-level values of added value, tertiary sector employment, the mean number of students, population density, structural regional type, and mean regional turnout in federal elections, as well as pretreatment values of all covariates from the baseline model (Table 9 in the Annex).

Table 1
Effects on ICT Startups.

DV: Start-up rate	0	A	B	C	D
Hackerspace, binary		1.0087		1.0110	
		(0.42)		(0.47)	
Hackerspace, time-dependent			1.0092**		1.0109**
			(2.75)		(2.96)
ICT patent stock	1.0953***	1.0957***	1.0770***	1.0973***	1.0709***
	(7.46)	(7.47)	(5.43)	(7.29)	(4.51)
Higher education institution	1.0273	1.0253	1.0273	1.0225	1.0236
	(0.56)	(0.52)	(0.56)	(0.45)	(0.48)
Incoming migration rate	1.0177**	1.0178**	1.0173**	1.0173**	1.0172**
	(3.20)	(3.21)	(3.11)	(3.06)	(3.06)
Share of young inhabitants	1.0458***	1.0449***	1.0383***	1.0464***	1.0425***
	(4.13)	(3.98)	(3.38)	(3.98)	(3.64)
Unemployment rate	0.9615***	0.9615***	0.9598***	0.9637***	0.9625***
	(−8.07)	(−8.07)	(−8.35)	(−7.30)	(−7.55)
GDP per capita	0.9981	0.9981	0.9977	0.9984	0.9984
	(−0.78)	(−0.79)	(−0.96)	(−0.66)	(−0.67)
Venture capital rate	1.0668	1.0678	1.0599	1.0742	1.0591
	(1.37)	(1.39)	(1.23)	(1.50)	(1.20)
Share of creative class	1.1606***	1.1612***	1.1440***	1.1625***	1.1386***
	(12.33)	(12.31)	(10.23)	(12.12)	(9.10)
Propensity score				0.9968	0.9331
				(−0.05)	(−1.10)
Observations	5200	5200	5200	4815	4815
AIC	21795.0	21796.8	21789.4	20340.8	20332.3
BIC	21926.1	21934.5	21927.0	20483.4	20474.8
N_g	400	400	400	400	400
k	21	22	22	23	23
ll	−10877.5	−10877.4	−10873.7	−10148.4	−10144.1
chi2	3348.1	3348.1	3357.2	3238.3	3249.5

Exponentiated coefficients; t statistics in parentheses.
Year dummy coefficients not reported.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

innovation commons effect. Summary statistics of all the variables entering the estimations are reported in Table 9 of the Annex. The selection of covariates is based on the above discussion of regional determinants in the related literature. To control for general time trends in entrepreneurial activity, we also use the full set of year dummies that captures variation over time that is common to all counties. For the sake of conciseness, the estimated year coefficients are not reported or discussed in the main part, but can be found in Table 2 of the Annex.

The set of controls includes two variables at the NUTS1-level: the amount of venture capital invested per civilian labour force as a measure of access to financial support and facilitation of start-up activities, and the share of (insured) artists in the civilian labour force as an indicator for the overall relevance of the creative class in the respective *Laender*.

The remaining variables are measured at the county level (NUTS3): the local unemployment rate as a measure of the 'necessity' to become self-employed, GDP per capita as a measure of local affluence and economic strength, the presence of a higher education institution as a measure of the local knowledge base and the size of the skilled talent pool, the share of young inhabitants as a measure of risk and digital affinity of the local population, the rate of incoming migration as a measure of the inflow of new ideas and knowledge, and the stock of ICT patents as a measure of the local knowledge base in the relevant sector. The next section discusses our main results and presents robustness checks.

5. Main results

5.1. From hackers to digital start-ups

The exploratory analysis confirms that local existence of hackerspaces is positively correlated with entrepreneurial activities in a given county. Table 1 provides quantitative evidence on a weak, but positive association of local hackerspace establishment with the digital start-up rate observed in German counties. Models 0, A and B show

Table 2
Effects on ICT Startups (estimated year coefficients).

DV: Start-up rate	0	A	B	C	D
Year=2001	1	1	1	1	1
	(.)	(.)	(.)	(.)	(.)
Year=2002	0.7920***	0.7919***	0.7906***	0.7956***	0.7951***
	(−10.07)	(−10.07)	(−10.14)	(−9.36)	(−9.39)
Year=2003	0.8033***	0.8029***	0.8027***	0.8050***	0.8073***
	(−9.30)	(−9.31)	(−9.33)	(−8.75)	(−8.64)
Year=2004	0.8833***	0.8826***	0.8850***	0.8798***	0.8865***
	(−5.23)	(−5.24)	(−5.14)	(−5.10)	(−4.77)
Year=2005	0.9099***	0.9090***	0.9132***	0.9014***	0.9113***
	(−3.89)	(−3.91)	(−3.73)	(−4.00)	(−3.55)
Year=2006	1.0401	1.0390	1.0496	1.0312	1.0489
	(1.42)	(1.38)	(1.74)	(1.04)	(1.59)
Year=2007	1.0477	1.0465	1.0578*	1.0387	1.0588
	(1.72)	(1.67)	(2.06)	(1.30)	(1.91)
Year=2008	0.9450*	0.9438*	0.9520	0.9392*	0.9564
	(−2.06)	(−2.09)	(−1.78)	(−2.10)	(−1.46)
Year=2009	1.1580***	1.1561***	1.1637***	1.1520***	1.1744***
	(5.35)	(5.24)	(5.52)	(4.62)	(5.13)
Year=2010	1.1661***	1.1636***	1.1675***	1.1598***	1.1813***
	(5.77)	(5.59)	(5.82)	(4.81)	(5.29)
Year=2011	1.0696*	1.0670*	1.0689*	1.0634	1.0835*
	(2.38)	(2.25)	(2.36)	(1.85)	(2.37)
Year=2012	0.9213*	0.9190*	0.9189**	0.9162*	0.9318
	(−2.54)	(−2.57)	(−2.62)	(−2.37)	(−1.89)
Year=2013	0.7969***	0.7947***	0.7928***	0.7924***	0.8055***
	(−6.68)	(−6.64)	(−6.83)	(−5.91)	(−5.44)
Observations	5200	5200	5200	4815	4815

Exponentiated coefficients; t statistics in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3
Effects on ICT Startups, only regions without hackerspaces before 2000.

DV: Start-up rate	0	A	B
Hackerspace, binary		1.0254	
		(1.04)	
Hackerspace, time-dependent			1.0169***
			(3.37)
ICT patent stock	0.9501	0.9451	0.9314
	(−1.35)	(−1.47)	(−1.85)
Higher education institution	1.0119	1.0054	1.0028
	(0.24)	(0.11)	(0.06)
Incoming migration rate	1.0119*	1.0124*	1.0126*
	(2.04)	(2.12)	(2.16)
Share of young inhabitants	1.0431**	1.0419**	1.0402**
	(3.02)	(2.93)	(2.81)
Unemployment rate	0.9777***	0.9783***	0.9782***
	(−4.06)	(−3.94)	(−3.97)
GDP per capita	0.9988	0.9991	0.9985
	(−0.45)	(−0.35)	(−0.59)
Venture capital rate	1.0672	1.0694	1.0781
	(0.82)	(0.84)	(0.94)
Share of creative class	1.1485***	1.1492***	1.1389**
	(3.30)	(3.31)	(3.09)
Propensity score	1.0921	1.0574	0.9355
	(1.37)	(0.78)	(−0.84)
Observations	4698	4698	4698
AIC	19487.3	19488.2	19477.9
BIC	19622.8	19630.2	19619.9
N_g	391	391	391
k	22	23	23
ll	−9722.6	−9722.1	−9717.0
chi2	1583.8	1584.7	1594.2

Exponentiated coefficients; t statistics in parentheses.
Year dummy coefficients not reported.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4
Effects on ICT Startups, only urban regions.

DV: Start-up rate	0	A	B
Hackerspace, binary		1.0160	
		(0.66)	
Hackerspace, time-dependent			1.0101**
			(2.66)
ICT patent stock	1.1002***	1.0999***	1.0763***
	(7.21)	(7.18)	(4.70)
Higher education institution	0.9959	0.9908	0.9942
	(−0.08)	(−0.17)	(−0.11)
Incoming migration rate	1.0153**	1.0156**	1.0155**
	(2.68)	(2.73)	(2.72)
Share of young inhabitants	1.0571***	1.0567***	1.0527***
	(4.43)	(4.39)	(4.06)
Unemployment rate	0.9586***	0.9590***	0.9576***
	(−6.72)	(−6.60)	(−6.86)
GDP per capita	0.9990	0.9991	0.9990
	(−0.40)	(−0.36)	(−0.40)
Venture capital rate	1.1036*	1.1039*	1.0898
	(2.00)	(2.01)	(1.74)
Share of creative class	1.1615***	1.1617***	1.1394***
	(11.53)	(11.54)	(8.78)
Propensity score	1.0272	1.0074	0.9557
	(0.43)	(0.11)	(−0.67)
Observations	2562	2562	2562
AIC	12334.4	12335.9	12329.3
BIC	12457.2	12464.6	12458.0
N_g	203	203	203
k	22	23	23
ll	−6146.2	−6146.0	−6142.7
chi2	2862.1	2862.5	2871.9

Exponentiated coefficients; t statistics in parentheses.
Year dummy coefficients not reported.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

baseline estimates; models C and D include propensity scores estimates as an additional covariate aiming to correct for some of the endogeneity in our model. Bias correction increases the size of the estimated coefficients. Moreover, the estimated effect on start-ups seems to grow over time, once a hackerspace is established in a county. The binary hackerspace indicator is not able to capture the dynamic nature of this association. It is the alternative, time-dependent hackerspace indicator in model B and D that shows a statistically significant coefficient. Based on the Akaike and Bayesian information criterion, this is our preferred model specification because it can explain a higher proportion of the observed variation in start-up rates. Overall, measurable effects from local hackerspace existence seem to unfold over time.[24]

Estimates from model C correct for some of endogeneity bias described above. Results suggest that having a hackerspace in place makes counties, on average, about 1 percent more productive in generating ICT start-ups. However, this effect is too small to be statistically significant. The association of hacker activities with new business formation can only be observed over time when accounting for the total number of years since first establishment. Estimates from model D suggest that, on average, each year of hackerspace existence increases the digital start-up rate by about 1 percent. Some hackerspaces have already been established in the 80's and existed for more than 25 years in 2013. Accordingly, more than one fourth of the total ICT start-ups in these regions can be statistically attributed to the longer operations of hackerspaces in these places. In light of these potentially strong dynamics, the observation window of 13 years from 2001 to 2013 might still be too short and warrant a cautious interpretation of the results. Yet, our exploratory study hints at a positive role of hacker communities on local ICT business formation. In order to further validate and check the robustness of results, we run additional regressions for a number of subsamples.

Since our results may hinge upon a few early hackerspaces, we rerun the same (bias-corrected) estimations for a reduced sample, now excluding counties with local hackerspaces established before the year 2000. Since we have no data on firm formation before that date, we cannot rule out the possibility that hackerspaces had different effects on start-ups during this early period, even though there is no indication that this was the case. The downside is that we are eliminating several important urban agglomerations from the data (namely, Berlin, Cologne, Hamburg, and Munich). Nevertheless, the results are largely confirmed for this reduced sample (Table 3 and Fig. 5 in the Annex showing predictive margins). Moreover, the estimated time-dependent effect of hackerspaces on ICT business formation is about 55 percent higher and the association is now slightly more pronounced: Each additional year of existence increases the regional start-up rate by almost 1.7 percent.

Second, the results are also confirmed when the sample is restricted to urban districts (Table 4 in the Annex), or urban districts that only see hackerspaces emerge after the year 2000 (results not reported, upon request from the authors). However, we cannot observe any significant hackerspace effects when using a subsample of rural counties (Table 5). Further to that, none of the standard controls that typically would explain variation in local start-up rates yields a statistically significant coefficient estimate. It seems that, in general, digital start-up rates in rural areas are determined by factors other than those observed. It remains an open research question which factors these might be.

Third, the comparison between urban and rural districts also provides some preliminary evidence that the effects of hackerspaces on

[24] Unfortunately, the lack of reliable data does not allow to further distinguish effects as we cannot directly observe, for example, the growth of local hacker communities (say, the number of members over time) vis-à-vis the accumulation of opportunity-revealing information in the local commons structures, nor can we observe the totality of entrepreneurial experimentation in a given county.

Table 5
Effects on ICT Startups, only rural regions.

DV: Start-up rate	0	A	B
Hackerspace, binary		0.8813	
		(−1.01)	
Hackerspace, time-dependent			1.0090
			(0.41)
ICT patent stock	1.3306	1.3715	1.3354
	(0.65)	(0.72)	(0.66)
Higher education institution	1.1162	1.1140	1.1179
	(0.93)	(0.92)	(0.95)
Incoming migration rate	1.0341	1.0358	1.0335
	(0.88)	(0.92)	(0.86)
Share of young inhabitants	1.0097	1.0132	1.0103
	(0.23)	(0.31)	(0.24)
Unemployment rate	0.9830	0.9833	0.9832
	(−1.62)	(−1.60)	(−1.60)
GDP per capita	0.9978	0.9981	0.9977
	(−0.31)	(−0.28)	(−0.32)
Venture capital rate	0.6705	0.6723	0.6718
	(−1.68)	(−1.67)	(−1.67)
Share of creative class	1.0821	1.0802	1.0826
	(0.77)	(0.75)	(0.78)
Propensity score	1.0318	1.1536	1.0116
	(0.10)	(0.44)	(0.04)
Observations	2253	2253	2253
AIC	8001.4	8002.4	8003.2
BIC	8121.5	8128.2	8129.1
N_g	197	197	197
k	22	23	23
ll	−3979.7	−3979.2	−3979.6
chi2	419.98	421.02	420.13

Exponentiated coefficients; t statistics in parentheses.
Year dummy coefficients not reported.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6
Estimation of propensity scores, pretreatment values as covariates.

DV: Hackerspace establishment	logit model
Structural region type	−.2044
	(−1.88)
Population density	.0005 ***
	(3.65)
Value added	.2802
	(1.12)
(Value added)^2	−.0005
	(−0.13)
(Value added)^3	−.0001
	(−0.57)
Total students	.0259***
	(5.01)
(Total students)^2	−.0001 ***
	(−6.13)
Tertiary sector employment	.0687 ***
	(5.56)
Election turnout	−.1200***
	(−4.96)
Civilian labour force	.0001 ***
	(2.63)
ICT patent stock	1.9557 ***
	(6.07)
Incoming migration rate	−.0379
	(−0.68)
Share of young inhabitants	.7098 ***
	(4.86)
GDP per capita	−.0194
	(−1.71)
Share of creative class	.3785 ***
	(2.96)
Const.	−14.404**
	(−2.57)
Observations	5200
Pseudo R2	0.4718
ll	−778.5
chi2	1390.78

t statistics in parentheses.
Year dummy coefficients and county ids not reported.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

digital entrepreneurship might be highly context-dependent. As some of the recent economic geography literature suggests, 'micro-agglomerations' and close co-location in urban context can play an important role for sharing and learning effects to fully unfold in a given region (Madaleno et al., 2018). Notably, based on our exploratory approach, it seems that hackerspaces established in rural regions (as opposed to urban) do not yield the same positive association with digital entrepreneurial outcomes and regional development. There is a series of interesting results regarding the control variables, which we turn to in the next section.

5.2. Other effects

In the following, we refer to results from Table 1, if not indicated otherwise. At large, the relationship of ICT patents invented by residents on local start-up activities is not clear-cut. In our main specification (Table 1), the estimated patent stock effect is always significant and positive. This confirms and extends generic findings from the regional entrepreneurship literature to the case of digital start-ups. Entrepreneurs are thus 'standing on the shoulders of giants' and they may successfully source know-how and information from other inventors located in the region. So, a larger pool of 'proprietary' knowledge is typically associated with more digital firm formation. In some model specifications, an additional one thousand ICT patents is related to a 10 percent increase in the rate of creation of new start-ups (Table 1, models 0, A and C). However, effects are not fully robust and again seem to depend on the specific context. They render insignificant or yield negative coefficients for the subsample of counties where hackerspaces were established after the year 2000 (Table 3), and for the subsample of rural counties (Table 5). Moreover, as the patent stock is continuously growing, it interferes with the hackerspace indicators and coefficients loose explanatory power once we include time-trending indicators in models (Table 1, models B and D).

Second, unemployment rates have a highly significant, negative effect on firm formation. Counties that suffer from high unemployment see significantly lower start-up activity. More specifically, an increase of the unemployment rate by one percentage-point lowers the incidence rate by about four percent. This link is robust across all model specifications. Accordingly, start-ups in the digital sectors are predominantly not created out of 'necessity', but rather in the pursuit of technological and commercial opportunities.

Third, counties with a larger share of young inhabitants in the total population evidence significantly higher digital start-up rates. An increase in the share of young inhabitants by one percentage-point is associated with a three to four percent increase of incidence rates. Arguably, early adoption of technologies and higher digital affinity of the younger people in the region as well as lower risk aversion among them enlarges the pool of potential entrepreneurs and aspiring talents new digital firms can recruit from. At the same time, this also might create more favourable local demand conditions for the new goods and services that digital start-ups provide.

Fourth, inward migration to counties is positively correlated with digital start-up rates. The inflow of human capital and people carrying tacit information and complementing new ideas to the existing pool of local knowledge increase entrepreneurial activities in the county. An additional inward-migrant per one hundred inhabitants increases the incidence rate by 1 to 2 percent.

Finally, there is also a strong positive association of the 'creative class' indicator, i.e. the labour-population-weighted number of artists

Table 7
Covariate-balance table.

Variable	Sample	Mean(treated)	Mean(control)	p.c. bias	p.c. bias reduction	t-test t	$(p > t)$
Structural region type	Unmatched	1.561	2.6546	−114.4		−22.06	0.000
	Matched	1.561	1.8943	−34.9	69.5	−4.22	0.000
Population density	Unmatched	3164.9	1691.1	131.4		30.98	0.000
	Matched	3164.9	2587.7	51.5	60.8	5.46	0.000
Value added	Unmatched	57.835	49.847	78.5		17.51	0.000
	Matched	57.835	55.106	26.8	65.8	2.94	0.003
Total students	Unmatched	68.181	17.962	104.8		23.85	0.000
	Matched	68.181	58.32	20.6	80.4	2.07	0.039
Tertiary sector empl.	Unmatched	79.281	68.237	127.6		24.26	0.000
	Matched	79.281	75.949	38.5	69.8	4.67	0.000
Election turnout	Unmatched	73.358	73.331	0.8		0.14	0.890
	Matched	73.358	73.081	7.8	(−906.6)	0.98	0.327
Civilian labour force	Unmatched	260000	91043	72.1		30.92	0.000
	Matched	260000	130000	57.2	20.6	5.87	0.000
ICT patent stock	Unmatched	0.56446	0.11898	60.7		24.87	0.000
	Matched	0.56446	0.21934	47	22.5	4.81	0.000
Incoming migration	Unmatched	5.5577	4.0341	79.2		18.98	0.000
	Matched	5.5577	5.2778	14.5	81.6	1.55	0.121
Young inhabitants	Unmatched	7.0922	5.623	140.9		32.58	0.000
	Matched	7.0922	6.6211	45.2	67.9	4.55	0.000
GDP per capita	Unmatched	40.222	26.899	98.2		22.79	0.000
	Matched	40.222	36.35	28.5	70.9	2.98	0.003
Share of creative class	Unmatched	3.3552	2.8277	38.4		11.43	0.000
	Matched	3.3552	2.8841	34.3	10.7	3.69	0.000

* If variance ratio outside [0.83; 1.21]for U and [0.83; 1.21] for M.

Table 8
Selected IT and web-based codes in the North American Industry Classification System (NAICS 2012).

NAICS code	Description
334111	Electronic Computer Manufacturing
334112	Computer Storage Device Manufacturing
334118	Computer Terminal and Other Computer Peripheral Equipment Manufacturing
334210	Telephone Apparatus Manufacturing
334220	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing
334290	Other Communications Equipment Manufacturing
334310	Audio and Video Equipment Manufacturing
334412	Bare Printed Circuit Board Manufacturing
334413	Semiconductor and Related Device Manufacturing
334416	Capacitor, Resistor, Coil, Transformer, and Other Inductor Manufacturing
334417	Electronic Connector Manufacturing
334418	Printed Circuit Assembly (Electronic Assembly) Manufacturing
334419	Other Electronic Component Manufacturing
334613	Blank Magnetic and Optical Recording Media Manufacturing
334614	Software and Other Prerecorded Compact Disc, Tape, and Record Producing
454111	Electronic Shopping
454112	Electronic Auctions
454113	Mail-Order Houses
511210	Software Publishers
515111	Radio Networks
515112	Radio Stations
515120	Television Broadcasting
515210	Cable and Other Subscription Programming
517110	Wired Telecommunications Carriers
517210	Wireless Telecommunications Carriers (except Satellite)
517410	Satellite Telecommunications
517919	All Other Telecommunications
518210	Data Processing, Hosting, and Related Services
519130	Internet Publishing and Broadcasting and Web Search Portals
541511	Custom Computer Programming Services
541512	Computer Systems Design Services
541513	Computer Facilities Management Services
541519	Other Computer Related Services
541810	Advertising Agencies

in each *Bundesland*, and the local firm formation in digital sectors. An increase by one in thousand inhabitants elevates the expected number of start-ups per civilian labour force by 13 to 16 percent.[25] This seems to well align with previous findings emphasizing the role of ‘subculture’ (Audretsch et al., 2017), ‘middleground’ groups and ‘bohemian’ communities (Cohendet et al., 2018), which might also

[25] Moreover, as the number of people considered the local creative class is constantly growing throughout the observation period, it interferes with the hackerspace indicators and looses some of its explanatory power once time-trending hackerspace indicators are included.

Table 9
Summary statistics, full sample.

Variable description	Obs.	Mean	Std. Dev.	Min	Max
Dependent variables					
Number of local ICT startups per year	5200	12.69	36.84	0	787
ICT startup rate per 1000 workers	5226	.09	.08	0	.66
Explanatory variables					
Hackerspaces, binary variable	5200	.08	.27	0	1
Hackerspaces, years of existence	5226	.66	3.13	0	33
Control variables at NUTS3-level					
Unemployment rate	5200	8.54	4.41	1.2	25.4
GDP per capita in 1000 Euro	5200	27.90	12.47	11.3	129.7
Share of young inhabitants	5200	5.73	1.03	3.7	11.3
Incoming migrants per 1000 inhabitants	5200	41.42	18.14	13.9	418.2
Higher education institution, binary variable	5200	.37	.48	0	1
Number of ICT patents filed per year	4800	.10	.27	0	5.22
Control variables at NUTS1-level					
Venture capital per 1000 workers	5200	.08	.07	.00	.86
Share of artists per 1000 workers	5200	2.87	.99	.86	13.30
Exposure variable					
Number of workers in civilian labour force	5200	104618.6	116044.6	19324	1795581
Control variables, logit sample					
Structural region type	5200	2.57	1.03	1	4
Population density	5200	1811.86	1023.98	491	6234.7
Value added	5200	50.50	9.29	36.02	110.44
Total students	5200	22.08	43.86	0	278.63
Tertiary sector employment share	5200	69.14	9.50	38.97	92.35
Federal election turnout	5200	73.33	3.93	61.2	82

determine entrepreneurial and innovation performance in a location. However, our results reflect correlations in the data and do not identify causal relationships. So, even though creative class 'workers' might improve local quality of life and outside attractiveness of a region, artists might 'co-locate' in regions where there are many entrepreneurs, simply for consumptive reasons (Nathan, 2007). In the next section, we discuss limitations of the exploratory framework and identify potential routes for future research.

6. Discussion and open research questions

Our findings provide first-hand empirical evidence corroborating the idea that hackerspaces are conducive to new firm formation in a region. Our main results suggest that the longevity of hackerspaces significantly correlates with start-up formation. This lends strong support to the conceptual argument that assemblage and sharing of complementary information within hackerspaces is time-dependent and, accordingly, it will take several years for the effects on entrepreneurial performance to unfold in a given region. At large, however, hackerspaces as open and informal supporting facilities are an important factor in local ecosystems for new firm formation.

6.1. Methodological aspects

Still, the research approach we have chosen is not without limits. It will take further empirical work to fully assess the role of hackerspaces in regional ecosystems. An increase in entrepreneurship rates is only one of multiple potential effects of hackerspaces on the economic development of regions.[26] Analysing county-panel data may reveal a link between observed characteristics, but it cannot reveal the true economic mechanisms governing this relationship. The exploratory approach developed in this paper is limited to the observed correlation of local hackerspace existence and higher digital start-up rates across German counties. Given the limited granularity of the data available to us and the obvious limitations of the research design, the current approach does not allow for causal effect identification.

Arguably, missing temporal and contextual factors can limit the generalizability of our findings. For example, it is not entirely clear how far exploratory findings generalize to other technologies and sectors. Arguably, the establishment of hackerspaces and their impact on start-up activities could hinge on specific and inherent properties of digital technologies. More than other technologies, they allow for almost frictionless knowledge transfer through nearly complete codification, sequential development and gradual improvement (rather than radical innovation), building on the work of others and modular tasks being conducive to knowledge exchange and collective review in communities. Although generalizability to other technologies may be constrained, our exploratory approach provides robust empirical evidence with regard to the relative importance of hackerspaces for local business formation in digital sectors.

6.2. Future research

First and foremost, new research should be directed to overcome some of the main methodological issues and limitations described in the previous section. Based on a more rigorous research design and with more granular data becoming available over time, we trust future empirical research in this area will allow for identification of causal hackerspace effects on new firm formation. Similarly, we believe follow-up research might want to understand the underlying economic mechanisms that govern the assemblage of complementary information in hackerspaces and the type of information exchanged and generated inside user communities. Moreover, it would be of great interest to study the point in time when hackerspace users transition and decide to become more independent and aspiring entrepreneurs, based on the commercial opportunity revealed to them. In particular, one could investigate how this interacts and reshapes activities in the hackerspace and how persistent innovation commons structures and assemblage of information can be over time.

[26] Social aspects such as community building, empowerment, participation and self-determined learning certainly have an impact on the local economy as well, but are deliberately left out here when the focus is on the formation of start-ups.

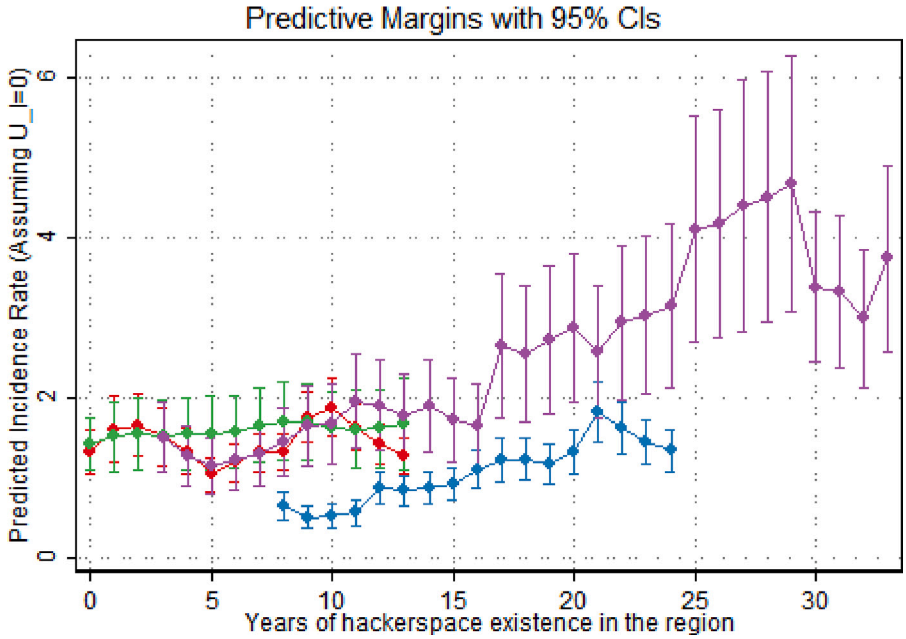

Fig. 5. Predictive margins on the local ICT startup rate (y-axis) over the years of hackerspace existence (x-axis).
Notes: Estimates are based on the following subsamples. Urban regions with hackerspaces established before the year 2000 (purple), urban regions with hackerspaces installed after 2000 (green), rural regions with hackerspaces established before the year 2000 (blue), rural regions with hackerspaces installed after 2000 (red). Covariates as in baseline model D of Table 1. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The quality of entrepreneurial outcomes also matters. A focus on 'innovative' start-ups as an outcome measure would refine our current approach to the data.[27] As yet another promising extensions for future research, one could instead observe entrepreneurial action and behaviour more closely and from earlier on. This would bring entrepreneurial experimentation, the discovery of entrepreneurial opportunities and the selection process around opportunities in the innovation commons to the forefront of the analysis (rather than measuring formal business registrations). Moreover, it would be interesting to study other measures of entrepreneurial performance as well, such as the relative survival rate of innovation commons-based ventures. In a similar vein, one might investigate the dynamics and 'resilience' of (innovation) commons structures, once information and opportunities are absorbed by local user entrepreneurs. Or, arguably, the value of commons structures depreciates the more mature technology becomes. Notwithstanding these methodological limitations and open questions, our findings provide important takeaways for policy.

6.3. Policy implications

Innovation policy is often underdeveloped when it comes to the support of innovation and entrepreneurs in user communities and non-commercial areas such as hackerspaces (Lakhani and Harhoff, 2016). This is surprising as this kind of support holds the potential to promote social welfare and help diffuse general purpose technology for a wider set of (digital) applications and contexts (Bresnahan and Trajtenberg, 1995). Related innovation activities are commonly less well recognized in policy-making for various reasons (Bradonjic et al., 2019). New household or community-born ideas and successful 'common' innovation outcomes (Foray, 2015) might diffuse less well and at a much slower pace (ultimately, possibly entering or not entering commercial spheres), they might not be advertised and therefore less visible to the general public, or legitimate interest may be poorly represented in the policy discourse when it comes to the allocation of public funding to this diverse group of actors and institutions (Potts, 2019). This also applies to the provisioning of small-scale infrastructure such as hackerspaces. In addition, non-commercially driven entities such as hackerspaces may find it more difficult to sustain activities based on the collection of membership fees, compared to, for example, commercially-driven incubator services which more frequently rely on their tenants and other sources of external funding from the private sector. At the same time, arguably, it could be that the design of public policies in this new area is indeed very challenging. For example, typically, public funds targeting users and user communities (e.g. via the provisioning of public space, or financial support for the documentation and codification of activities) cannot be distributed based on merits and reputation, so other criteria will need to be developed. Rarely, commercial or academic records and reputation will exist, or, if anything, such proof will only exist for some users in communities. Moreover, funding and eligibility criteria would need to make sure that self-governance and openness features of communities are largely preserved and continue to allow for bottom-up initiative.[28] This might further explain why evidence on policy-making and experimentation in this area is particularly scarce.

One notable exception is the existing policy initiatives in additive manufacturing – a nascent technology and hardware also used in many hackerspaces – such as the 'America Makes' public–private partnership in the U.S. or similar initiatives in Germany are largely focused on innovation funding to large-scale industry activity (EFI, 2015). Another example on a national level is the public funding made available via the Everyone Innovation Fund for establishing makerspaces in U.K.

[27] Our data does not allow to distinguish 'innovative' from other types of entrepreneurial ventures, even though there is no clear-cut definition of the former (on definitional issues, see Fritsch, 2018). Also, digital start-ups that do not (formally) register their business activities are not captured by the ORBIS data.

[28] In an ideal world, the public intervention would not impact user selection into communities as well as it would interfere with community practices and overall direction. Moreover, in some instances, attempts to carefully design and require such interventions to be incentive-neutral may sit square with the general ambition to hold policies accountable and measure their tangible policy outcomes.

libraries. In Germany, the Prototype Fund[29] was set up in 2016 to support open source projects of public interest in an inclusive and easily accessible way. Similar funding projects exist on European levels, some of which are linked to university funds and educational policies.[30] At large, however, our findings together with the brief review of existing policy efforts suggest that support to innovative communities of hackerspaces and similar facilities is currently underdeveloped. This is clearly calling for a more inclusive approach to innovation and entrepreneurship policies, beyond traditional public support measures and established agents of change such as firms and universities.

Second, notably, the effect of hackerspaces we explore in this study is often not based on public policy intervention in counties and self-standing supporting facilities might be temporary solutions to address market failure in regional firm formation. In Germany in particular, many hackerspaces can be traced back to a decentralized, grassroot movement, deeply grounded in the private and collective initiative of local users. This means it is also well-tailored to local demand and needs which, if anything, suggests that a bottom-up design of policies might be preferable. However, it is unclear whether market failure persists at more mature stages of digital technology and when most complementary information has been shared in local commons structures, and even when effects only unfold in longer-term as our main results indicate. Arguably, in some instances and locations, innovation commons infrastructures might cease to exist once such failure is largely fixed. And, yet it is unclear if the private initiative would re-emerge on local levels and suffice to fix similar problems with the next generation of nascent technologies and distributed information on entrepreneurial opportunities, tech use and development in households. From a policy perspective and in light of our findings, this suggest that any intervention should be carefully set up and designed in order not to crowd out initiative and private incentives from local users. Moreover, policy timing of public interventions will matter for the effectiveness of policies and, accordingly, a potential (temporary) support to hackerspaces and similar supporting facilities should be evaluated and monitored on a continuous basis.

Finally, different to broader cluster policy and a substantial body of evidence around them (Boschma and Fornahl, 2011), the new wave of co-location tools and 'middleground' intermediary platforms such as hackerspaces (Cohendet et al., 2021) are too little understood from a policy perspective and the evaluation literature in this area is still relatively scarce (Madaleno et al., 2018). As argued before, business incubators and accelerators provide for an alternative, but often much more selective measure to help the formation of new firms.[31] They differ in terms of their stronger commercial orientation, and the intense mentoring and networking services in these environments. In contrast, hackerspaces often allow for multiple directions and have more diverse agendas, not necessarily targeting innovation and new tech uses but also encouraging technical problem-solving, repair, activism, play or other leisure time activity. Arguably, less heavily 'curated' communities such as hackerspaces might also attract tech enthusiasts with no commercial or entrepreneurial intent in the first place, but that are motivated by self-rewards or see their motivation changed over time (Halbinger, 2018). However, based on the evidence available to us, there is a lack of comparative studies that would enable the assessment of the relative effectiveness of co-location tools which could help guide their selection. Again, at large, this calls, on the one hand, for a more science-based approach to policy development and experimentation in this new policy area and, on the other hand, for a more inclusive set up of overall policy measures. The latter aspect could potentially serve as an important point of entry for an alternative set of innovation agents in the 'middleground', so far largely ignored and little considered on the policy agenda (Cohendet et al., 2018, 2021).

7. Conclusion

In this paper, we are first to explore and provide quantitative evidence for a weak positive correlation between hackerspaces and digital entrepreneurship in regions. In a series of fixed-effect Poisson panel models, we find that the existence of a hackerspace can help explain some of the variation in start-up rates observed between 2001 and 2014. The longer a local hackerspace exists, the higher is the digital start-up rate as measured by the annual number of newly founded firms per civilian worker. Results continue to hold once we correct for some of the plausible treatment selection and omitted variable bias in our data using propensity score matching methods, as hackerspaces are not randomly assigned to regions but are more likely to emerge from larger population of tech-savvy users and aspiring entrepreneurs.

Still, tentative findings point to the great importance of hackerspaces as a prime example of innovation commons structures and, potentially, a novel explanation for new firm formation in regions. Hackerspaces as supporting facilities help generate and reveal valuable, complementary information on nascent technology and entrepreneurial opportunities that is otherwise dispersed and privately held by users. With more empirical research on the horizon, a new generation of regional and entrepreneurial policies might also want to consider the support of hackerspaces. This could potentially bring in an alternative set of innovation agents in the 'middleground', previously not accounted for by most policies. The findings of this paper suggest that hackerspaces, at least in urban contexts, have been instrumental in fostering digital entrepreneurship in Germany and expanding the range of commercial opportunities.

CRediT authorship contribution statement

Alexander Cuntz: Conceptualization, Investigation, Methodology, Formal analysis, Writing, Visualization, Project administration. **Jan Peuckert:** Conceptualization, Investigation, Methodology, Formal analysis, Writing, Visualization, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

The authors would like to thank the editor and three anonymous reviewers, as well as Carsten Fink, Florian Kern, Prince Oguguo and participants at the 2018 International Association for the Study of the Commons (IASC) Workshop on New Commons, Oldenburg, and the British Council's Creative Spark 2020 Workshop on Entrepreneurship, Creativity and Europe, Berlin, for valuable comments on earlier versions of this paper. We also gratefully acknowledge Jan-Philipp Mesenbrock for excellent technical assistance.

[29] https://www.prototypefund.de/en/

[30] Some of these funds have been implemented via European Regional Development Funds (ERDF).

[31] Accelerators are often operated by venture capitalists who take equity stakes in participating early-stage firms. In comparison, many incubators types typically offer 'lighter-touch' support to more start-ups over longer periods. While participation in both types of tools seems to increase employment in new firms, accelerators also positively affect subsequent external funding available to these firms (Madaleno et al., 2018). Evidence on survival of new firms is mixed.

Funding

One author received financial support from the German Federal Ministry of Education and Research (BMBF) under grant number 16IF108.

Disclaimer

The views expressed are those of the authors, and do not reflect the views of the World Intellectual Property Organization (WIPO) or its member states.

Annex

See Tables 2–9 and Fig. 5.

References

Acs, Z., Anselin, L., Varga, A., 2002. Patents and innovation counts as measures of regional production of new knowledge. Res. Policy 31 (7), 1069–1085.

Acs, Z., Autio, E., Szerb, L., 2014. National systems of entrepreneurship: Measurement issues and policy implications. Res. Policy 43 (3), 476–494.

Acs, Z., Desai, S., Hessels, J., 2008. Entrepreneurship, economic development and institutions. Small Bus. Econ. 31 (3), 219–234, URL https://EconPapers.repec.org/RePEc:kap:sbusec:v:31:y:2008:i:3:p:219-234.

Acs, Z., Stam, E., Audretsch, D., O'Connor, A., 2017. The lineages of the entrepreneurial ecosystem approach. Small Bus. Econ. 49, http://dx.doi.org/10.1007/s11187-017-9864-8.

Agarwal-Tronetti, R., Shah, S.K., 2014. Knowledge sources of entrepreneurship: Firm formation by academic, user & employee innovators. Res. Policy 43, 1109–1133.

Allen, D.W.E., 2017. Hackerspaces as entrepreneurial anarchy. Available At SSRN 2749016.

Allen, D.W.E., Potts, J., 2016a. The Origin of the Entrepreneur and the Role of the Innovation Commons. SSRN Scholarly Paper ID 2867850, Social Science Research Network, Rochester, NY.

Allen, D.W.E., Potts, J., 2016b. How innovation commons contribute to discovering and developing new technologies. Int. J. Commons 10 (2), 1035–1054.

Amabile, T.M., 1988. From individual creativity to organizational innovation. In: Gronhaug, K., Kaufmann, G. (Eds.), Innovation: A Cross-Disciplinary Perspective. Norwegian University Press.

Amin, A., Thrift, N. (Eds.), 1995. Globalization, Institutions, and Regional Development in Europe. Oxford University Press.

Anderson, C., 2012. Makers: The New Industrial Revolution, first ed. Crown Business, New York, ISBN: 978-0-307-72095-5 978-0-307-72097-9.

Audretsch, D., Lehmann, E., Seitz, N., 2017. Cultural Amenities, Subcultures and Entrepreneurship. Working paper.

Baldwin, C., Hienerth, C., von Hippel, E., 2006. How user innovations become commercial products: A theoretical investigation and case study. Res. Policy 35, 1291–1313.

Bénabou, R., Tirole, J., 2006. Incentives and prosocial behavior. Amer. Econ. Rev. 96 (5), 1652–1678.

Bester, H., 1985. Screening vs. rationing in credit markets with imperfect information. Am. Econ. Rev. 75 (4), 850–855.

Bonander, C., Jakobsson, N., Podestà, F., Svensson, M., 2016. Universities as engines for regional growth? Using the synthetic control method to analyze the effects of research universities. Reg. Sci. Urban Econ. 60.

Boschma, R., Fornahl, D., 2011. Cluster evolution and a roadmap for future research. Reg. Stud. 45 (10), 1295–1298.

Boutillier, S., Capdevila, I., Dupont, L., Morel, L., 2020. Collaborative Spaces Promoting Creativity and Innovation. J. Innov. Econ. Manage. 31 (1), 1–9. http://dx.doi.org/10.3917/jie.031.0001, URL https://www.cairn.info/revue-journal-of-innovation-economics-2020-1-page-1.htm.

Bradonjic, P., Franke, N., Lüthje, C., 2019. Decision-makers' underestimation of user innovation. Res. Policy 48 (6), 1354–1361.

Bresnahan, T., Trajtenberg, M., 1995. General purpose technologies 'Engines of growth'? J. Econometrics 65 (1), 83–108, URL https://EconPapers.repec.org/RePEc:eee:econom:v:65:y:1995:i:1:p:83-108.

Browder, R.E., Aldrich, H.E., Bradley, S.W., 2019. The emergence of the maker movement: Implications for entrepreneurship research. J. Bus. Ventur. 34 (3), 459–476, Publisher: Elsevier. URL https://ideas.repec.org/a/eee/jbvent/v34y2019i3p459-476.html.

Carpenter, R.E., Petersen, B.C., 2002. Capital market imperfections, high-tech investment, and new equity financing. Econ. J. 112 (477), F54–F72.

Cassar, G., 2004. The financing of business start-ups. J. Bus. Ventur. 19 (2), 261–283.

Cohendet, P., Creplet, F., Dupouët, O., 2001. Organisational innovation, communities of practice and epistemic communities: the case of linux. In: Kirman, A., Zimmermann, J.-B. (Eds.), Economics with Heterogeneous Interacting Agents. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 303–326.

Cohendet, P., Grandadam, D., Mehouachi, C., Simon, L., 2018. The local, the global and the industry common: the case of the video game industry. J. Econ. Geogr. 18 (5), 1045–1068.

Cohendet, P., Grandadam, D., Suire, R., 2021. Reconsidering the dynamics of local knowledge creation: Middlegrounds and local innovation commons in the case of FabLabs. Z. Wirtschaftsgeographie 65 (1), 1–11. http://dx.doi.org/10.1515/zfw-2020-0042, (ISSN: 2365-7693, 0044-3751)URL https://www.degruyter.com/document/doi/10.1515/zfw-2020-0042/html.

Cooper, A.C., Gimeno-Gascon, F.J., 1990. Entrepreneurs, Processes of Founding, and New Firm Performance. Institute for Research in the Behavioral, Economic, and Management Sciences.

Cowan, R., Zinovyeva, N., 2013. University effects on regional innovation. Res. Policy 42 (3), 788–800.

D'Agostino, Jr., R.B., 1998. Propensity score methods for bias reduction in the comparison of a treatment to a non-randomized control group. Stat. Med. 17 (19), 2265–2281.

Davis, T.J., Stetson, C.P., 1984. Creating successful venture-backed companies. J. Bus. Strategy 5, 45–58.

Dorsey, T., 1979. Operating guidelines for effective venture capital funds management' in 'improving new venture performance: Some guidelines for success. Am. J. Small Bus. 11–25.

EFI, 2015. Report on Research, Innovation and Technological Performance in Germany 2015. Report 2015e, EFI - Commission of Experts for Research and Innovation, Berlin, ISBN: 978-3-00-049540-3, URL http://hdl.handle.net/10419/113892.

EFI, 2016. Report on Research, Innovation and Technological Performance in Germany 2016. Report 2016e, Commission of Experts for Research and Innovation (EFI), EFI - Commission of Experts for Research and Innovation, ISBN: 978-3-00-053303-7, URL http://hdl.handle.net/10419/146399.

Elitzur, R., Gavious, A., 2003. Contracting, signaling, and moral hazard: a model of entrepreneurs,'angels,'and venture capitalists. J. Bus. Ventur. 18 (6), 709–725.

Evans, D.S., Jovanovic, B., 1989. An estimated model of entrepreneurial choice under liquidity constraints. J. Polit. Econ. 97 (4), 808–827.

Fairlie, R., Fossen, F., 2019. Defining Opportunity Versus Necessity Entrepreneurship: Two Components of Business Creation. Technical Report w26377, National Bureau of Economic Research, Cambridge, MA, p. w26377. http://dx.doi.org/10.3386/w26377, URL http://www.nber.org/papers/w26377.pdf.

Falck, O., Fritsch, M., Heblich, S., 2011. The phantom of the opera: Cultural amenities, human capital, and regional economic growth. Labour Econ. 18 (6), 755–766.

Feldman, M.P., Audretsch, D., 1999. Innovation in cities:: Science-based diversity, specialization and localized competition. Eur. Econ. Rev. 43 (2), 409–429.

Ferdinand, J.-P., 2017. Entrepreneurship in Innovation Communities: Insights from 3d Printing Startups and the Dilemma of Open Source Hardware, first ed. Springer Berlin Heidelberg, New York, NY.

Foray, D., 2015. Common innovation (how we create the wealth of nations) in the light of reflections on mass flourishing (how grassroots innovation created jobs, challenge, and change). Res. Policy 44 (7), 1403–1405.

Franke, N., Shah, S.K., 2003. How communities support innovative activities: an exploration of assistance and sharing among end-users. Res. Policy 32 (1), 157–178.

Freiberger, P., Swaine, M., 1999. Fire in the Valley: The Making of the Personal Computer. McGraw-Hill, Professional.

Frey, B.S., Oberholzer-Gee, F., 1997. The cost of price incentives: An empirical analysis of motivation crowding- out. Am. Econ. Rev. (ISSN: 00028282) 87 (4), 746–755, URL http://www.jstor.org/stable/2951373.

Fritsch, M., 2018. The Regional Emergence of Innovative Start-Ups: A Research Agenda. Jena Economic Research Papers 2018–015, Friedrich-Schiller-University Jena.

Furman, J.L., Nagler, M., Watzinger, M., 2018. Disclosure and Subsequent Innovation: Evidence from the Patent Depository Library Program. Technical report, National Bureau of Economic Research.

Gershenfeld, N.A., 2005. Fab: The Coming Revolution on Your Desktop–from Personal Computers to Personal Fabrication. Basic Books, New York, ISBN: 978-0-465-02745-3.

Grandadam, D., Cohendet, P., Simon, L., 2013. Places, spaces and the dynamics of creativity: The video game industry in montreal. Reg. Stud. 47 (10), 1701–1714.

Granger, E., Watkins, T., Sergeant, J.C., Lunt, M., 2020. A review of the use of propensity score diagnostics in papers published in high-ranking medical journals. BMC Med. Res. Methodol. 20, 1–9.

Guimarães Pereira, Â., Panella, F., Ferretti, F., Wanner, M., Rosa, P., 2017. Overview of the Maker Movement in the European Union. Publications Office of the European Union, ISBN: 978-92-79-70525-0, URL https://data.europa.eu/doi/10.2760/227356.

Hackerspace.org, 2021. Website. URL https://hackerspaces.org/.

Halbinger, M.A., 2018. The role of makerspaces in supporting consumer innovation and diffusion: An empirical analysis. Res. Policy 47 (10), 2028–2036.

Hatch, M., 2014. The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers. McGraw-Hill Education, New York, ISBN: 978-0-07-182113-1 978-0-07-182112-4.

Isenberg, D., 2010. The big idea: How to start an entrepreneurial revolution. Harv. Bus. Rev. 88.

King, G., Nielsen, R., 2019. Why propensity scores should not be used for matching. Political Anal. 27 (4), 435–454.

Kostakis, V., Niaros, V., Giotitsas, C., 2015. Production and governance in hackerspaces: A manifestation of commons-based peer production in the physical realm? Int. J. Cult. Stud. 18 (5), 555–573.

Lakhani, K., Harhoff, D., 2016. Revolutionizing Innovation: Users, Communities, and Open Innovation. MIT Press, ISBN: 9780262029773.

Lange, B., Schüßler, E., 2018. Unpacking the middleground of creative cities: spatiotemporal dynamics in the configuration of the berlin design field. Reg. Stud. 52 (11), 1548–1558.

Langlois, R.N., Garzarelli, G., 2008. Of hackers and hairdressers: Modularity and the organizational economics of open-source collaboration. Ind. Innov. 15 (2), 125–143. http://dx.doi.org/10.1080/13662710801954559, (ISSN: 1366-2716, 1469-8390) URL https://www.tandfonline.com/doi/full/10.1080/13662710801954559.

Lewis, K., Massey, C., 2018. Youth entrepreneurship. In: Entrepreneurship: New Perspectives in a Global Age. Routledge, pp. 206–226.

Madaleno, M., Nathan, M., Overman, H., Waights, S., 2018. Incubators, Accelerators and Regional Economic Development. Cep Discussion Papers, Centre for Economic Performance, LSE.

Malecki, E.J., 1991. Technology and Economic Development: The Dynamics of Local, Regional, and National Change. Longman Scientific & Technical [u.a.], Harlow, ISBN: 978-0-582-01758-0 978-0-470-21723-8.

Maxigas, P., 2012. Hacklabs and hackerspaces: Tracing two genealogies. J. Peer Prod. (ISSN: 2213-5316) (2).

Mortara, L., Parisot, N.G., 2016. Through entrepreneurs' eyes: the Fab-spaces constellation. Int. J. Prod. Res. (ISSN: 0020-7543) 54 (23), 7158–7180. http://dx.doi.org/10.1080/00207543.2016.1198505.

Moyes, A., Westhead, P., 1990. Environments for new firm formation in great britain. Reg. Stud. 24 (2), 123–136. http://dx.doi.org/10.1080/00343409012331345844.

Mueller, S., Bakhirev, A., Böhm, M., Schröer, M., Krcmar, H., Welpe, I., 2017. Measuring and mapping the emergence of the digital economy: a comparison of the market capitalization in selected countries. Digit. Policy Regul. Gov. 19 (5), 367–382.

Mueller, S., Boehm, M., Krcmar, H., Welpe, I., 2016. Machbarkeitsstudie: Geschaeftsmodelle in Der Digitalen Wirtschaft. EFI, Studien zum deutschen Innovationssystem, Berlin.

Nathan, M., 2007. The Wrong Stuff? Creative Class Theory and Economic Performance in UK Cities. Mpra Paper, University Library of Munich, Germany.

Pfister, C., Rinawi, M., Harhoff, D., Backes-Gellner, U., 2016. Regional Innovation Effects of Applied Research Institutions. Economics of Education Working Paper Series 0117, University of Zurich, Department of Business Administration (IBW).

Potts, J., 2019. Innovation Commons: The Origin of Economic Growth. Oxford University Press, New York, NY, ISBN: 978-0-19-093749-2 978-0-19-093750-8.

Potts, J., Torrance, A.W., Harhoff, D., von Hippel, E., 2021. Social welfare gains from innovation commons: Theory, evidence, and policy implications. Available At SSRN 3915997.

Putnam, R.D., 1993. The prosperous community: Social capital and public life. Am. Prospect. (13), 35–42, URL http://prospect.org/.

Qian, H., 2010. Talent, creativity and regional economic performance: the case of China. Ann. Reg. Sci. 45 (1), 133–156.

Qian, H., Acs, Z.J., Stough, R.R., 2012. Regional systems of entrepreneurship: the nexus of human capital, knowledge and new firm formation. J. Econ. Geogr. 13 (4), 559–587.

Rothaermel, F.T., Thursby, M., 2005. Incubator firm failure or graduation?: The role of university linkages. Res. Policy 34 (7), 1076–1090, The Creation of Spin-off Firms at Public Research Institutions: Managerial and Policy Implcations.

Schäfer, S., Henn, S., 2018. The evolution of entrepreneurial ecosystems and the critical role of migrants. a phase-model based on a study of IT startups in the greater tel aviv area. Cambridge J. Reg. Econ. Soc. (ISSN: 1752-1378) 11 (2), 317–333. http://dx.doi.org/10.1093/cjres/rsy013, arXiv:https://academic.oup.com/cjres/article-pdf/11/2/317/33024744/rsy013.pdf.

Schulz, C., Wagner, S., 2008. Outlaw community innovations. Int. J. Innov. Manage. 12 (3), 399–418.

Shah, S.K., Mody, C.M., 2014. Creating a context for entrepreneurship: Examining how users' technological & organizational innovations set the stage for entrepreneurial activity. In: Governing Knowledge Commons. Oxford University Press.

Shah, S., Tripsas, M., 2016. When do user-innovators start firms? A theory of user entrepreneurship. In: Revolutionizing Innovation: Users, Communities and Open Innovation. MIT Press, pp. 285–307.

Shane, S.A., 2008. The Illusions of Entrepreneurship. Yale University Press.

Smith, A., 2017. Social Innovation, Democracy and Makerspaces. Technical report, SWPS, SPRU.

Smith, A., Hielscher, S., Dickel, S., Soderberg, J., van Oost, E., 2013. Grassroots digital fabrication and makerspaces: reconfiguring, relocating and recalibrating innovation? SSRN Electron. J. (ISSN: 1556-5068) http://dx.doi.org/10.2139/ssrn.2731835, URL http://www.ssrn.com/abstract=2731835.

Storper, M., Venables, A., 2004. Buzz: Face-to-face contact and the Urban economy. J. Econ. Geogr. 4, 351–370. http://dx.doi.org/10.1093/jnlecg/lbh027.

Stuetzer, M., Obschonka, M., Audretsch, D.B., Wyrwich, M., Rentfrow, P.J., Coombes, M., Shaw-Taylor, L., Satchell, M., 2016. Industry structure, entrepreneurship, and culture: An empirical analysis using historical coalfields. Eur. Econ. Rev. (ISSN: 0014-2921) 86, 52–72. http://dx.doi.org/10.1016/j.euroecorev.2015.08.012, URL https://www.sciencedirect.com/science/article/pii/S0014292115001294. The Economics of Entrepreneurship.

Svensson, P.O., Hartmann, R.K., 2018. Policies to promote user innovation: Makerspaces and clinician innovation in Swedish hospitals. Res. Policy (ISSN: 00487333) 47 (1), 277–288. http://dx.doi.org/10.1016/j.respol.2017.11.006, URL https://linkinghub.elsevier.com/retrieve/pii/S0048733317301919.

Thomke, S., von Hippel, E., 2002. Customers as innovators: A new way to create value. In: Harvard Business Review, April. pp. 74–81.

van Holm, E.J., 2014. What are Makerspaces, Hackerspaces, and Fab Labs? SSRN Scholarly Paper ID 2548211, Social Science Research Network, Rochester, NY, URL https://papers.ssrn.com/abstract=2548211.

van Holm, E.J., 2017. Makerspaces and Local Economic Development. Econ. Dev. Q. (ISSN: 0891-2424) 31 (2), 164–173. http://dx.doi.org/10.1177/0891242417690604.

von Hippel, E., 1986. Lead users: A source of novel product concepts. Manage. Sci. 32 (7), 791–805.

von Hippel, E., 2005. Democratizing Innovation. The MIT Press, Cambridge Mass.

von Hippel, E., 2007. Horizontal innovation networks by and for users. Ind. Corp. Change 16, 2.

von Hippel, E., 2017. Free Innovation. MIT Press, Cambridge, MA.

von Hippel, E., Paradiso, J., 2008. User innovation and hacking. IEEE Pervasive Comput. 7 (8), 66–69.

Walter-Herrmann, J., Büching, C. (Eds.), 2013. FabLab: of machines, makers and inventors. In: Cultural and Media Studies, transcript, Bielefeld, ISBN: 978-3-8394-2382-0 978-3-8376-2382-6.

Watts, H.D., 1981. The Branch Plant Economy : A Study of External Control. Longman.

Wellman, B., Boase, J., Chen, W., 2002. The networked nature of community on and off the internet. IT Soc. 1 (1), 151–165.

Wenger, E., 2004. Knowledge management as a doughnut: Shaping your knowledge strategy through communities of practice. Ivey Bus. J. 68 (3), 1–8.

Williams, M.R., Hall, J.C., 2015. Hackerspaces: a case study in the creation and management of a common pool resource. J. Inst. Econ. 11 (4), 769–781. http://dx.doi.org/10.1017/S1744137415000016, (ISSN: 1744-1374, 1744-1382). URL https://www.cambridge.org/core/product/identifier/S1744137415000016/type/journal_article.