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A theory of emergence: Knowledge, rewiring and innovation

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ABSTRACT

Why do social interactions linked to sharing knowledge drive the emergence of a regional technology economy? We proffer a positive theory and explanation-sketch identifying mechanisms and initial conditions in an explanation of emergence of a knowledge economy. We trace the emergence of a knowledge economy, from a small group of founding members to a regional technology economy. With the rapid influx of new people, knowledge spillover motivates technologists and entrepreneurs to reach out beyond existing contacts to explore the expanding knowledge economy and interact with new acquaintances in the search for novelty. In the course of network rewiring in knowledge clusters, individuals share knowledge and cooperate in innovation, and move to more central positions when they interact. Mirroring the trends of increased knowledge exploration and innovative activity at the individual level, new startup firms founded during this time period come to span a greater number of industry groups. Endogenous dynamics of overlapping knowledge networks lie behind the rapid morphogenesis of new regional technology economies in New York City and Los Angeles.

Specialized knowledge and knowhow underlie a division of knowledge in the technology sectors of advanced economies.[1] Specialization in economic life refers not just to human capital or points in an assembly line, but also to specialized knowledge and knowhow embedded in institutions and organizations outside the formal boundaries of the firm. This includes overlapping networks linking individual actors together in knowledge sharing and in informal advisory and innovative activity. We define *knowledge spillover* as a social process in which knowledge and knowhow—often tacit, uncodified and embodied—are shared: passed on from one individual to another through interpersonal communication, including face-to-face, email and online channels. Such knowledge flow through networks allows economic actors to innovate using new combinations and recombinations of technology and knowledge, and to benefit from timely information on access to finance capital, specialized knowledge workers, established technology firms, industrial labs, research universities, professional service providers and other such non-tradeable inputs (Owen-Smith and Powell 2004; DellaPosta and Nee 2020).

As distinct from economies that rely on physical inputs or natural resources, the knowledge economy depends critically on the intellectual capabilities of technologists and entrepreneurs interacting both within and across the boundaries of individual firms (Mokyr 2002, 2010). In innovation clusters, specialized knowledge underlies the positive externalities that follow when specialists with varying bits of knowledge are put in a position to interact and learn from one another. Knowledge spillover is in turn linked to

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[1] Charles Babbage proposed the idea of division of knowledge to characterize specialization in knowhow and knowledge, extending Adam Smith's concept of division of labor (Stigler and George 1991).

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agglomerative growth enabling self-reinforcing cumulative regional advantage (Marshall 1890; Saxenian 1994; Owen-Smith and Powell 2004). Such endogenous growth in regional economies draws in new workers who bring with them not only human capital but also specialized knowledge (Glaeser 1999). In Silicon Valley's knowledge economy, for instance, the global reach of networks of immigrant technologists connects established high technology and startup firms with emerging technology clusters in Asia and the Middle East, enabling knowledge sharing, innovation and capital to fund startup tech firms led by immigrant entrepreneurs (Saxenian 2006). Similarly, in New York City's knowledge economy, immigrant entrepreneurs with ties to Europe, Russia, East Asia, the Middle East and second-generation immigrant minority entrepreneurs contribute to a community ecology characterized by an ethnic and racial melting pot evident in networks of entrepreneurs and technologists (Nee and Drouhot 2020). The assimilation of immigrant minority tech entrepreneurs is reflected in shared normative beliefs .

In this article, we show how the emergence of a regional technology economy is enabled and motivated by social processes embedded in knowledge spillover and network rewiring. We focus on the community ecology of the knowledge economy of two metropolitan centers, New York and Los Angeles. We define community ecology as an organizational field comprised of multiple organizational forms in bounded ecological space. We proffer a positive theory that specifies knowledge spillover, network rewiring and shared group identity as social processes that explain growth of innovative activity enabling endogenous emergence of a knowledge economy. We extend a sociological approach to positive theory with a focus on "social mechanism—that is the social processes having consequences for designated parts of the social structure" (Merton 1968a:43), stated as propositions: more or less general statements of relationships between properties of social behavior (Homans 1974).[2] Our theory is sufficiently general that hypotheses can be derived and tested in studies of knowledge economies in both advanced and emerging market economies.[3] We employ mixed-methods research to provide an explanation-sketch—a partial explanation that consists of specification of causal mechanisms and initial condition that explain the emergence of a knowledge economy, first at the micro-level of individual actors and in a second part, at the meso-level of the emerging knowledge economy.

1. Theory of emergence

In *The Gifts of Athena: Historical Origins of the Knowledge Economy (2002)*, economist Joel Mokyr argues that the growth explosion in the modern West in the past two centuries was driven not just by the appearance of new technological ideas but also by the improved access to these ideas in society at large — as made possible by social networks linking universities, publishers, professional sciences, and kindred institutions. Given the rudimentary formal institutions of enforceable contracts and secure property rights in Britain during the Industrial Revolution, social norms and networks served as the cement for trust and credible commitment. Social norms facilitated cooperation and trust enabling prosocial behavior needed for knowledge sharing in overlapping networks of scientists, entrepreneurs, financiers and technical consultants. In Britain's Industrial Revolution, *rewiring* of networks connected the scientists, entrepreneurs, financiers and engineers in production of the principal technological advances: "The economic elite that led the Industrial Revolution consisted of subgroups ….Boulton found his Watt, Clegg his Murdoch, Marshall his Murray, and Cooke his Wheatstone (Mokyr 2010: 187)."

Fast forward to the twentieth century and the rise of the American knowledge economy. As Saxenian (1994) shows, overlapping networks facilitated knowledge spillover between university-based scientists, entrepreneurs, knowledge workers, engineers and venture capital contributed to the rapid pace of innovative activity. "Around every technological subject, or every engineering concern, you have meeting groups that tend to foster new ideas and innovate. People rub shoulders and share ideas" (Saxenian, 1994:34). With their dense spatial ecology, regional knowledge economies combine numerous factors that constitute a source of regional advantage (Storper et al. 2015). Within a bounded urban ecology, close human proximity of specialty trades fosters ease of impromptu meetings, enabling businesses to respond quickly to changing market conditions and benefit from a wide array of specialized trades (Uzzi 1996). The spatial density of employment opportunities and the attractiveness of urban life with its variety of educational and cultural programs assure a constant flow of new talent seeking an attractive and challenging place to live (Jacobs 1984; Moretti 2012). Greater concentrations of skilled workers spur new ideas and tend to increase entrepreneurial activities that can substantively shorten the time cities need to respond to changed market conditions (Glaeser 2008). A significant facet of dense urban ecology is the ease of information flow through word-of-mouth relational exchange by economic actors living and working in close proximity (Storper 2011). *Knowledge spillover* is facilitated by the close human contact afforded by cities, where there are abundant opportunities for face-to-face communication in cross-cutting, overlapping networks that comprise the social fabric of urban life. Ease of face-to-face encounters in dense ecological space has made global cities the central meeting points of creativity and innovation (Storper 1997; Glaeser 2011; Zukin 2020).

A paradox of open markets in metropolitan areas is that competition demands continuous innovation, which in turn requires cooperation . When norms enable prosocial behavior that maximizes the group's welfare, individual and corporate actors will collaborate to capture the benefits from cooperation (Nee and Ingram 1998; Nee 2005; Baldassarri 2015). Collaboration in sharing

[2] An example of Hempelian explanation sketch in sociology is Merton's (1968b) 'Matthew Effect' explaining inequities in science. Merton relies on quotes from Harriet Zuckerman's interviews with Nobel laureate scientists for more or less vague indications of social mechanisms and initial conditions considered as relevant to his explanation. Though his sketch was empirical, Merton did not seek confirmation. Confirmation of his theory came long afterwards with experimental tests of the Matthew Effect by Van de Rijt et al. (2014) and Bol et al. (2018).

[3] In positive theory, logically interreated propositions are general falsifiable statements (Homans 1974); but theory confirmation turns on derivation of empirically testable hypotheses (Hempel and Oppenheim 1948). See Hofman et al. (2017) on explanation and prediction.

knowledge and knowhow can compensate for lack of internal skills in a firm, and team members also acquire competence and reputation as effective cooperators in relational exchange (Owen-Smith and Powell 2004). The extent of knowledge spillover depends on the opportunity for interactions among individuals. Within social networks, individuals are continually updating their decisions regarding with whom to interact, which links to maintain, and which to discount (Owen-Smith and Powell 2004). As Powell and associates (2005: 1139–40) observed in the biotechnology industry: "The larger the number of pathways for communication and exchange, the more rapidly news percolates through the network. In turn, when more knowledge is exchanged, participants attend to their network partners more intensively (Powell 1990). The enhanced flow of ideas and skills then becomes an attraction, making the network more appealing to join. Rapid transmission and diverse participants enhance both the likelihood of recombination and the generation of novelty."

We define *rewiring* at the individual level as the social process when encounters or discerning exploration leads to cultivating new acquaintances. Since innovation often relies on access to new knowledge and knowhow, enterprising players are inclined to initiate relational exchanges with new acquaintances. Drawn to the growing diversity of knowledge-spillover events, both established players and new entrants reach out to others as they search for promising ideas and for specialized knowledge and knowhow. Rewiring of social patterns of co-attendance involves ongoing assessment of the utility of knowledge sharing under conditions of information asymmetry and uncertainty (Simon 1972, 1991). *Among alternative actions, a person will tend to choose one for which, as perceived by the actor, the value of a result multiplied by the probability of getting the result is the greater* (proposition I, Homans 1974). Homans's rationality proposition assumes information asymmetry, limited rationality, and rule-governed behavior embedded in shared normative beliefs; hence rational action is context bound (Simon 1957, 1978).

In the search to discover new combinations and recombinations of knowledge and knowhow to fuel innovative activity, rewiring of egocentric networks cumulatively drives boundary-crossing ties that link specialized knowledge in clusters. Actors who build reputations for facilitating cooperative behavior move to the center of networks (Padgett and Ansell 1993; Padgett 2012). In highly competitive markets, actors retain their position at the center only through continued renewal and cooperation in innovative activity outside the firm (Powell et al. 2005). Effective cooperators are not only rewarded with increased opportunities to produce resources that require collaboration but also are in a better position to be selected in the rewiring and expansion of their networks. This rewiring of patterns of relational exchange connects established players and new entrants drawn in from different industrial sectors, including from outside the regional economy, and facilitates innovative activity in the knowledge economy. Rewiring is also a social mechanism stabilizing cooperation because it tends to reward connections that have been helpful, or otherwise proved valuable, and enables actors to pull back from those that have not. Entrepreneurs who maintain productive connections that also allow them to acquire novelty through chance discovery of new combinations or recombination of existing knowhow and knowledge are more likely to succeed in their innovative endeavors. Hence, *the greater the expected payoff from knowledge spillover, the more economic actors will rewire to secure access to valued knowledge* (proposition II).

The economist Alfred Marshall (1920:27) observed that a key source of comparative advantage was the ease of knowledge spillover through networks of skilled workers living and working in close proximity in industrial districts, where "mysteries of the trade" are in the air. Marshall observed in his field research that knowledge spillover occurs, if and when "one man starts a new idea, it is taken by others and combined with suggestions of their own; and thus it becomes the source of further new ideas." Ideas that stimulate innovation often come from outside the circle of immediate relationships when the actor reaches out to meet other players (March 2010). Reaching out increases the likelihood of chance exchange with new acquaintances and strangers with knowhow and specialized knowledge that differs from the shared information of a closed network (Coleman 1988). When exploring small worlds outside an actor's immediate relationships, *the greater the payoff from knowledge spillover, the more likely it is that actors will rewire to enable ongoing innovative activity* (proposition III). Moreover, the extent of rewiring reflects both the volume and breadth of innovative activity in a knowledge cluster. Higher levels of rewiring in knowledge clusters are likely to correspond with a higher volume of innovative activity. A higher volume of innovative activity is more likely to realize new combinations and recombinations of technology and ideas. Hence, a high volume of innovative activity is more likely to generate innovations that can be brought to the market through entrepreneurial action. *The more extensive the rewiring, the more rapid the* pace *of innovation in the technology economy* (proposition IVa). *The greater the volume of innovation, the more rapid the emergence of an integrated knowledge economy* (proposition IVb).

2. Meetup.com as an economic institution of the knowledge economy

2.1. The institutional context of emergence

After the dotcom bubble crashed in 2000, the small but booming knowledge economy concentrated in midtown Manhattan folded, as dotcom firms on the stock market went into freefall. During the dotcom boom, New York City's tech entrepreneurs had looked to Silicon Valley for inspiration and guidance; but without the web of economic institutions of an established regional knowledge economy as in Silicon Valley, New York's fledgling "Silicon Alley" dotcom firms were unable to recover from the market crash. In 2002, amidst the ruins of Silicon Alley in midtown Manhattan, a young entrepreneur, Scott Heiferman, created Meetup.com. Heiferman's novel app facilitated organized participation in the New York Tech Meetup, bringing together a small group of like-minded technologists, first in his office and then, as the numbers of participants rapidly grew, in a monthly townhall-style meeting in the largest NYU auditorium in Washington Square (Cometto and Piol 2013). These events feature a selection of entrepreneurial teams who "pitch" their startup's innovation to a capacity audience of about 800 technologists, entrepreneurs, angel investors, executive of finance capital firms, and university-affiliated audience. The teams receive helpful feedback from the audience after their pitch, and the reception following a Meetup event provides opportunity to meet like-minded individuals. The monthly NY Tech Meetup townhall

assembly contributed to the consolidation of norms and networks enabling and motivating shared identity in the emerging organizational field, which in turn contributed to cooperation, trust and prosocial behavior.

As a website that allows social groups to organize and notify others of upcoming events, Meetup.com has grown to facilitate frequent face-to-face meetings of entrepreneurial technologists at multitudinous events ranging from social mixers to seminars and workshops organized by experts in a particular field, in numerous metropolitan areas. While the NY Tech Meetup offers an influential platform for entrepreneurs and technologists to interact with one another, there is also a diverse array of smaller nonprofit knowledge-sharing groups on Meetup.com that organize weekly meetup events where co-attendees can socialize and share ideas. Regular attendance at these social and specialized technical events enables and motivates network rewiring, as attendees have an ongoing opportunity to interact with new attendees. Knowledge spillover occurs spontaneously in the course of chance encounters at Meetup events and at follow-up face-to-face meetings. Participant observation at generalist NY Tech Meetup townhall assembly and smaller specialized Meetup events revealed a consistent social pattern of informal clusters of technologists talking and sharing information and knowhow before the formal knowledge spillover event, and at an informal social mixer over refreshments afterwards. In one-on-one conversations, it was commonplace for individuals to exchange business cards with a shared agreement to get together in a follow-up meeting. In both the generalist NY Tech Meetup and the specialist meetups, casual business attire and the prosocial orientation of co-attendees encourage ease of knowledge-sharing and rewiring through networking at social mixers following the event.

2.2. Explanation-sketch of knowledge spillover, network rewiring, and innovation

In field research conducted in Manhattan and Brooklyn, numerous tech entrepreneurs spoke of their own experience with social processes involving knowledge spillover and network rewiring at Meetup events.[4] The founder and CEO of Lessonface, a company specializing in online musical instruction, for example, said that:

> "Through the music tech meetups, I've met some really interesting music tech people in New York City. It's a very fun scene, and I met some very cool people I've continued to be in touch with, and they have been helpful. I think hearing your ideas out in front of a group can shine a bright light on what you're trying to do, and hearing the feedback, seeing the reaction of the room, for us, it's a source of teachers and students. And I think one of the primary benefits of Meetup events is that startups get to meet investors."[5]

Another entrepreneur explained that:

> "Part of it is just having some community, some other people that are out there. The act of starting a company is a lonely thing. And then the act of participating, which is really what most of these Meetups are, whether giving advice or talking or participating, it's rewarding because then you don't feel alone anymore. You feel like you're part of a community and you feel connected and you want to give into this to continue that connection. Most of the people that I work with or give advice, or direct to the right place, they're not competitors, they're just people trying to start companies just like myself, so why not give the benefit of your advice."[6]

Other economic institutions in the City also promote knowledge spillover and network rewiring among tech entrepreneurs. These include the General Assembly and the Flatiron School, both of which offer short-term training courses. *Accelerators* like Entrepreneur Roundtable and Techstars provide high-powered inhouse advisory by experienced tech entrepreneurs and access to venture capital at the early stage startups. *Incubators* nurture startups at an early stage when the entrepreneur has an idea but needs to develop a business model and product. In his interview, the founder and CEO of Proper Cloth, a company specializing in made-to-order, custom-fit shirts, described his incubator experience:

> "The incubator was fantastic for many reasons. For technical help, there were some very talented developers working out of there. Weird, intricate database questions, server questions. But also like for brainstorming ideas to think, you know, what's a new marketing idea. These were folks that could speak that language, were aware of what was happening in the different kinds of industry around here. And you could really get good ideas from them. And so sounding boards for ideas, some technical help. And then a lot of emotional support I think is actually very important. Because this is a period where you're not being successful for a while. And it's 11:30 at night and you're in the office but there's other people in the office and they're working too. Having those people around you helped I think to keep things in perspective and keep your dream alive a little bit and insulate you from people in the rest of the world who work at a job and pay their rent or their mortgage or are being a responsible person in some way like that. And you don't feel like you're so alone doing this stupid idea."[7]

[4] Participating in the field research were members of the Economic Sociology Lab, post-doc Todd Bridges and graduate students, Daniel Della-Posta, Mario Molina and Lisha Liu. Interviews (113 from 2013 to 2018) with founders of start-up tech firms were conducted in New York City by Victor Nee, Todd Bridges, Brett de Bary and Sonja Opper.

[5] Claire Cunningham, onsite interview, September 5, 2018.

[6] Michael Sid, founder and CEO of Mediamorph, onsite interview, September 6, 2018.

[7] Seph Skerritt, founder and CEO of Proper Cloth, onsite interview, October 18, 2018.

A common experience at the startup stage is to share office space with other tech entrepreneurs. Numerous NYC lofts have been converted into shared office spaces with inexpensive rents.

Additionally, established big tech and venture capital occasionally provide improvised office space in their firm's office building to promising entrepreneurs at the start-up stage:

> "The availability of open source capabilities has lowered a lot of technical barriers and capital barriers to company formation. Other key inputs, and perhaps I think one of the best and most important ones is there's a very collegial, almost collaborative attitude within a lot of the New York tech companies. It's as if people are willing to sort of take each other in because this person is working on something really interesting. We've got a couple of spare desks in the corner, these guys are incubating a new company, we like one of the guys so we'll give them a place to live for a while. They can drink our coffee and our beers on Friday nights and we wish them well. It is encouraged by geographic proximity. It's encouraged and reinforced by a lot of other common ground: lifestyle habits, age, pedigree in terms of education. It's also partly a byproduct of the absence of capital, believe it or not. In other words, I think New York entrepreneurs have been making do and helping each other get to a certain point. I know there's more capital available than there has been before, but I think there's that collaborative, collegial ethic that we see in a lot of companies here and a lot of mutual reinforcement in an incredibly positive way. I like it better than the Valley."[8]

Our focal organizational actors are entrepreneurs who search for new combinations and recombinations of knowledge and knowhow to found a technology-enabled firm. As Schumpeter (1934:66) underscored, the entrepreneur's 'function' is to seek novelty to bring to the market by founding a new firm: "New combinations, are, as a rule, embodied, as it were in new firms which generally do not arise out of the old ones but start producing beside them ….in general it is not the owners of stage-coaches who build railways." From a total population of 990 CEOs and founders of startup technology firms listed on the City's "Made in NYC" database, 503 entrepreneurs participated in the 2014 firm-level survey. These tech entrepreneurs had founded new firms after the dotcom crash in a diverse range of industrial sectors, including e-commerce, advertising, finance, health, artificial intelligence (AI), blockchain, environ-tech, software services, big data solutions, education, hospitality, social media, and hardware devices. Slightly more than half (53%) of them either "pitched" their innovation and business models at the NY Tech Meetup or attended regularly for an average time span of 2.9 years. They are predominantly college-educated, with a sizeable number holding an MA, MBA or PhD. Those with an MA degree were more likely than other college graduates to have founded health-tech firms, those with an MBA degree were more likely to have founded e-commerce firms, and those with a PhD were more likely to have founded AI firms. Only 4% did not have a college degree. A majority (83%) report a father having a white-collar profession. Female entrepreneurs make up 12% of the sample. Approximately 45% of the entrepreneurs in the sample were either first or second-generation immigrants, from East Asia, Europe, Israel, South Asia or Turkey. Fig. 1a shows the distribution of the number of close business contacts that respondents reported first meeting at one of the events hosted by NY Tech Meetup. Nearly a third (30%) of respondents who attended meetup events in 2014 reported in 2018 that they had met at least one of their closest five business relationships at such an event. Fig. 1b shows that most entrepreneurs have only known their closest business ties for fewer than 10 years, during a period of emergence and rapid growth of New York City's knowledge economy.

The entrepreneurs ($N = 171$) resurveyed in 2018 were asked about the nature of the relationship with their five closest business ties. The most common type of collaborative tie in their closest business relationship was "sharing and/or collaborating on a good idea" and reciprocal exchange of business advice (60%). All the other areas of cooperation with their five closest business relationships (see Fig. 1c) also involved sharing information and/or knowledge: "joint technology development/technical problem-solving" (5%), "mutual information sharing" (7%), "connections to tech talent from universities or colleges" (3%), "referral/introduction to tech talent" (3%), "referral/introduction of new customers" (9%), and "help with external financing" (3%). The results from the two-wave survey (2014 and 2018) of entrepreneurs who founded start-up tech firms point to a link between "sharing and/or collaborating on a good idea" and rewiring. Fig. 1b shows that knowledge sharing and innovative activity leading to ongoing social interactions between tech entrepreneurs who founded startup firms and another player are overwhelmingly network ties established during the period of rapid emergence of NYC's knowledge economy.

The abundance of gathering places on the narrow island of Manhattan such as cafes, restaurants, bars, cultural events, public lectures and seminars enable chance encounters and social interaction. A common street-level experience of living in Manhattan:

> "I walk down the street every day, and there's something new happening, somebody new I've never seen. This constant kind of jumble of ideas and people is really the best environment for inputs for creativity, because marketing is about interacting with culture."[9]

The urban ecology of mid and lower Manhattan facilitates ease of chance social interaction with friends and acquaintances, as well as unexpected encounters with novelty.

[8] CEO of BRE Ventures, onsite interview, 2018.

[9] Ben Guttmann, founder and CEO of Digital Natives Group, onsite interview, April 22, 2015.

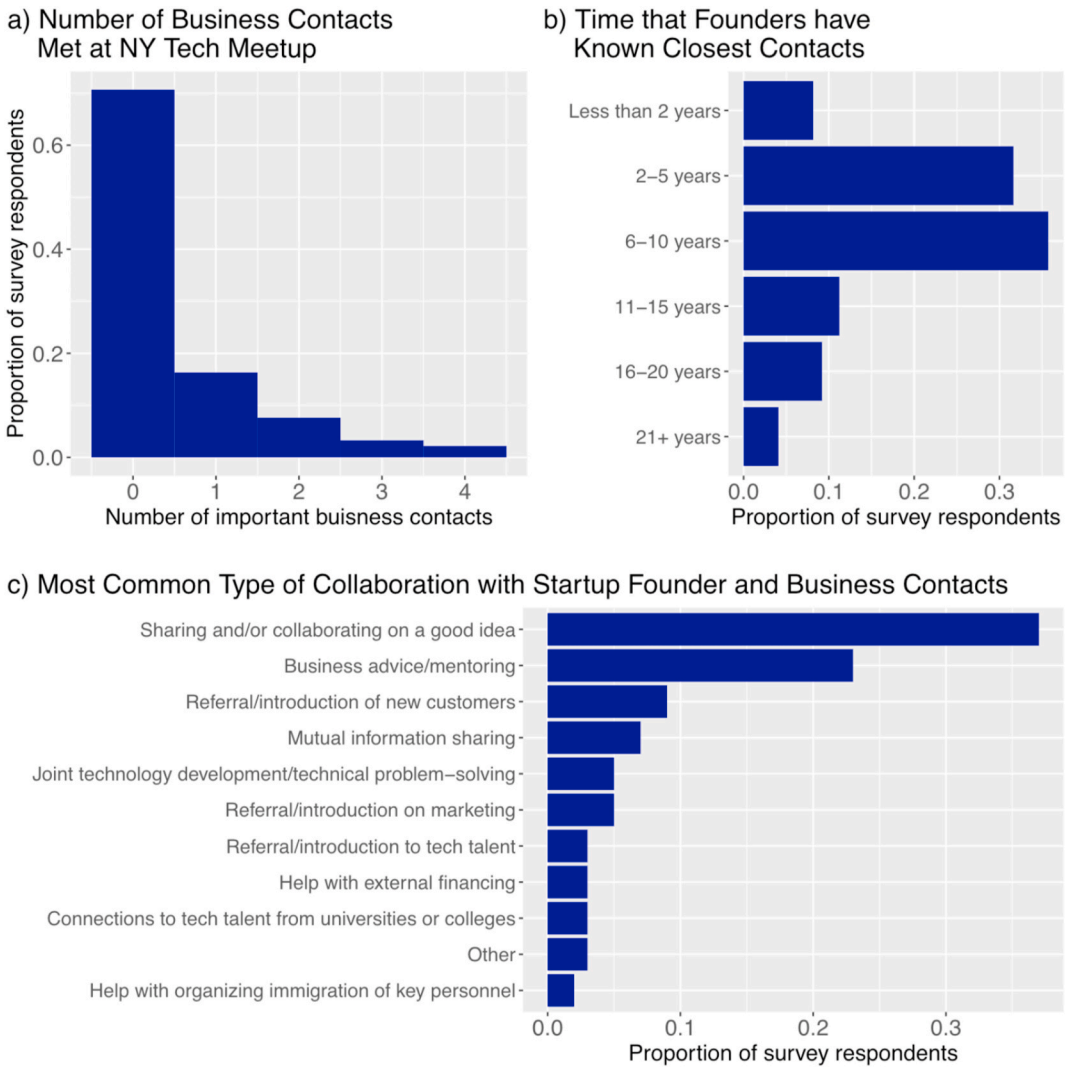

Fig. 1. a) The proportion of important business contacts that founders of technology startups reported meeting at a NY Tech Meetup event (out of those who have attended); b) the average time that startup founders have known their closest business contacts at the time of the second-wave survey (2018); c) the most common types of collaboration with business contacts reported by startup founders respondents.

> "People network a lot so I might go to events probably every night of the week, well not every night, maybe four or five nights a week. You go someplace, you run into someone who has an idea or is involved in the business and next thing you know it's a catalyst for great conversation and great and wonderful collaboration. That I think is the secret sauce of New York."[10]

> "New York is extraordinary, for you can be walking down the street and run into somebody you haven't seen for two years. You can go to a tech gathering, and you can meet somebody that you have not spoken to in six months. And so, the ecosystem surfaces people again, regularly. You cross each other's paths in a way that somewhere like the spread-out Bay Area, you're not gonna do that as often. And so, you network, you meet people, they will resurface whether you deliberately reconnect with them or not."[11]

Another entrepreneur described his networks metaphorically: "It's kind of like a spider with a web, and making your way into that spider web in New York."[12]

[10] Coppy Holzman, founder and CEO of Charitybuzz; onsite interview, April 22, 2015.
[11] Cindy Gallop, founder and CEO of IfWeRanTheWorld and MakeLoveNotPorn, interview at a WeWork office, September 12, 2018.
[12] Elliot Cohen, founder and CEO of Citymaps, acquired by TripAdvisor; onsite interview, April 21, 2015.

2.3. Initial condition enabling and motivating knowledge spillover and network rewiring

Indirect reciprocity—the willingness of community members to reward cooperators and punish defectors—makes cooperation sustainable even in larger networks where players oftentimes engage with changing players in one-shot transactions. Such willingness tends to be tied to the new acquaintance's reputation or, when this is not yet known, to community members' confidence that they can learn about this. People tend to be more likely to trust new acquaintances if there is some intermediary connection and/or if they are fairly confident that they would hear or could readily find out about any significant bad behavior:

> "I can see friends of friends and extended networks. How I know someone puts a lot of context around it. There's more accountability, so within a network where you're fairly well connected, you can use those relationships as proxies for people that you don't yet know. I know that somebody's reputation is important to them if they want to be an ongoing member and interact in this community, and so I have some security around the fact that if they do wrong by me—and not that I would intentionally slander their name—that it's gonna get around."[13]

If the probability of learning about the reputation (or image) of other players is larger than the cost-benefit ratio of being altruistic towards others, indirect reciprocity is an individually rational and therefore stable outcome (Nowak and Karl 1998). Cooperation is more likely to evolve as the number of interactions increases within any given population.

But as networks grow and become more inclusive over time, cooperation is increasingly difficult to establish, given the costs associated with spreading information among large enough sub-populations. This is not a problem in ongoing social networks where transmission of reputational information is a byproduct of social interaction. Within spatially concentrated cities, players are acutely aware that their reputation can be damaged through negative gossip, while being regarded as a 'valuable community member' can be expected to have a future pay-off. Even if you and the other person involved in a particular transaction never meet again, there is a calculable chance that not only others in your peer group will learn about your behavior through multiple networks, but your potential clients will learn about your action as well. As a venture capital entrepreneur noted, the interconnectivity of start-up tech firms "means you're at the distance of a hop being one or two, at most. Assume there is a venture capitalist out there and everybody talks with him. It's just kind of the nature of the beast. And then if you're on the blotter, that's the way I see it, and then any given person has a hundred friends or so."[14] Quite naturally, with this level of connectedness and overlapping interest, 'paying forward' quickly emerged as a dominant strategy in New York's tech economy. Players intuitively grasp the rule of thumb that cooperation establishes a good reputation and will be rewarded (Nowak 2006). Even with the expectation that reputation built in the past will generate future returns, individual benefactors have no guarantee that the utility of future return favors from a third party will exceed the costs assumed through one's own pro-social behavior. In real-world settings, helping others can incur real costs in the form of time invested and knowledge shared, which are concerns that understandably affect most players in their decision 'to pay it forward'. Yet, in spite of uncertain future net-returns, cooperation among tech entrepreneurs and knowledge workers is more common than individual economic rationality would predict.

In New York City's emergent high-technology economy, the "Made in NYC" label on a prominent website of more than 600 internet firms contributes to a shared identity. Shared identity reinforces norms of prosociality and cooperation in this regional economy where players recognize that a promising new start-up firm's success has positive externalities for the community, as in the adage "a rising tide lifts all boats." Group-level prosociality goes beyond expectation of indirect reciprocity, "I scratch your back and someone else will scratch mine," insofar as positive externalities benefit the industrial cluster through agglomeration effects and a systems-level feedback loop that benefits a player's own firm (Nee and Opper 2012; Padgett and Powell 2012). In sum, shared identity facilitates prosociality and cooperation in innovative activity.

Even with the expectation that reputation built in the past will generate future returns, individual benefactors have no guarantee that the utility of future returns from a third party will exceed the costs assumed through one's own prosocial behavior. In real world settings, helping others can incur real costs in the form of time invested and knowledge shared, which understandably affects most players in their decision to "pay it forward." Yet, in spite of uncertain future net-returns, cooperation is more common than individual economic rationality would predict. In this sense, prosociality is a behavioral principle fostering cooperation in larger human groups, once direct reciprocity and kinship no longer suffice to maintain stable cooperation. The assumption is that growing individual specialization and increasing interdependence of group members fosters the emergence of a collective intentionality helping the group to survive and thrive in spite of challenging or even hostile inter-group competition (Tomasello et al. 2012).

Motivation to help strengthen the community development as a whole by extending help to other individuals involves some selectivity when it comes to the question whom to help. Paying forward makes intuitively more sense when it supports members of the community who are 'valuable' not only in a moral sense as being prior cooperators, but also in an economically rational sense, as being likely to make a difference to the group's overall fitness. In spite of the generally collaborative atmosphere and the desire to reciprocate for the help once received, people are naturally inclined to devote more help and mentoring to winning projects. As one entrepreneur reasons, "Of course, I want to help people where the help will be meaningful in the end."[15]

This underlying rationality triggers a strong spirit of competitiveness where new entrants into the community compete to solicit the

[13] Aber Geiger, founder and CEO of Insight; onsite interview, March 28, 2013.
[14] Lucas Nelson, Gotham Ventures capital firm, interview conducted in a mid-town café, March 11, 2014.
[15] Onsite interview, 2013.

best mentoring, and mentors seek out the best and most deserving projects. The right match of mentor and protégée ultimately will make a big difference not only for the individual beneficiary, but for the community at large, which needs to identify and support rising stars. After all, it is the growing visibility of big players, the attention media pays to large "exits," and the high concentration of new market entrants that help to bring in further resources—human capital and venture capital—needed to secure Manhattan's entry onto the global map of regional knowledge-based economies. This is why "everyone wants to see everyone do well, and a lot of that's tied to New York, because they wanna see New York do well."[16] Mutual interdependence within groups fosters what we call group-mindedness as a behavioral principle.

> "There is this sort of common feeling of like we're in this larger ecosystem and we're sort of competing against the other industries in a larger meta-way than we are competing against one another. I love taking calls and helping others, I do it all the time. So I think maybe that's what it is, maybe we feel like we're having the rising tides lifting all boats in the space, and it's less about I want my boat to rise faster than the next guy's in this Pacific Ocean that we're in!"[17]

"Community, yes, that's why we band together! We're trying to help each other and cooperate, in a way that makes New York City—that paints New York City in a positive light in terms of technology; that is, what is happening here."[18] Prosocial behavior, cooperation and trust in the emerging knowledge economy enabled and motivated by normative beliefs embedded in the emerging knowledge economy facilitate knowledge spillover and network rewiring.

Ongoing social interactions commonly involve overlapping networks of diverse players from different ethnic and racial groups, including immigrants and second generation immigrant minorities. Shared group identity embedded in social norms and overlapping networks in the emerging organizational field of the knowledge economy enable cooperation and trust across diverse social groups. The shared identity of players in the emerging organizational field is evident in the ethnic composition of social networks. At the individual level, networks of tech entrepreneurs are structurally similar and inclusive, reflecting the extent of melting pot assimilation in NYC's emerging knowledge economy (Nee and Drouhot 2020).

Fig. 2 illustrates empirically the extent to which social norms in the knowledge economy are enforced through informal social sanctions and reputational effects. The data comes from the first of two surveys of tech entrepreneurs who founded startup firms in Manhattan and Brooklyn conducted in 2014. Strong norms listed in 2a focus on shared normative informal rules of fair-play in competition between technology entrepreneurs, and weak norms lists normative beliefs sanctioned through reputational effects. Social norms embedded in cross-cutting networks facilitate prosocial behavior, cooperation and trust in the knowledge economy. We find evidence of a relatively high level of consensus across all groups on sanctioning of "strong" social norms in the emerging knowledge economy.

3. Behavioral sketch of endogenous emergence

We collected data from Meetup.com through its public API at the beginning of 2020, focusing on two large metropolitan regions, New York City and Los Angeles. Meetup.com enables knowledge spillover, rewiring through enterprising technologists who organize events large and small featuring useful knowledge and technology of interest to like-minded peers, and repeat social interactions in overlapping networks motivating cooperation, trust and prosocial behavior reinforcing shared identity in the tech ecosystem. In New York City, knowledge spillover through networks is facilitated by the locational advantages of a narrow island offering abundant opportunities for face-to-face communication in dense urban neighborhoods. By contrast, in the Los Angeles basin, the sprawling metropolitan region is dotted with smaller cities and urban neighborhoods distributed across a vast urban ecology, integrated by an interconnected maze of freeways and boulevards. During lengthy rush hours, traffic congestion routinely discourages face-to-face meetings beyond the smaller urban communities of the Los Angeles metropolitan region. Despite the differences in urban ecology, entrepreneurs in both metropolitan regions participate in in-person knowledge spillover in the search for useful knowledge and novelty.

For New York, we gathered the list of all Manhattan or Brooklyn-based Meetup groups that are categorized by the platform as "tech" and have hosted at least one Meetup event. 1,992 technology Meetup groups meet these criteria; altogether, between the start of 2005 and the end of 2019, these groups hosted over 70,000 events, attended by over 272,000 unique individuals. We gathered a similar list of Meetup groups based within a 20-mile radius around the city of Los Angeles, which includes 963 technology groups, hosting over 42,000 events, attended by over 99,000 unique individuals between the start of 2007 and the end of 2019. We consider anyone who has attended an event hosted by a technology Meetup group to be a member of the community that forms the New York or Los Angeles knowledge economy. New members can enter by attending an event for the first time, and members may exit by no longer attending any more events. Newcomers can easily join open-access Meetup groups and attend in-person events hosted by them. Meetup groups themselves are also categorized under specific topics (e.g., entrepreneurship, programming, social, legal, etc.), which further allows us to trace knowledge specialties through any individual's group affiliations.

Preliminary observations of the Meetup data reflect a high rate of growth from 2007 to 2015 in the numbers of individuals who signed up for local technology-focused events, as well as a sharply increasing number of interests embodied by community members

[16] Onsite interview, 2013.
[17] Murat Aktihanoglu, founder and CEO of Entrepreneur Roundtable, on site interview, March 18, 2013.
[18] CEO of Big Human, onsite interview, February 20, 2013.

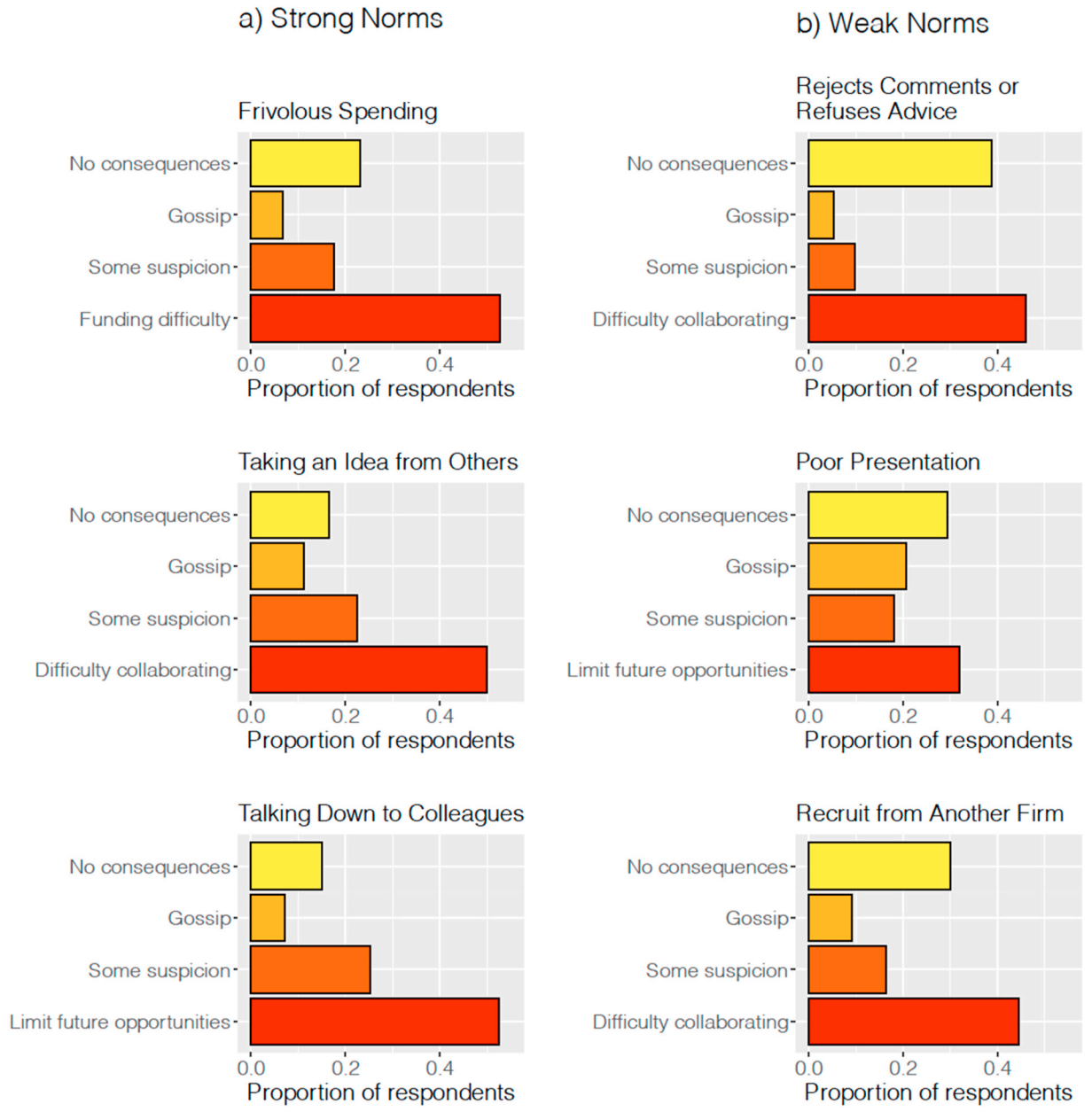

Fig. 2. Strong (a) and weak (b) norms of the knowledge economy.

(see Fig. 3). Through a combination of event attendance records, self-reported interest topics and topic categories of Meetup groups that an individual has joined, we track behavioral traces of technologists and entrepreneurs as they move from one type of knowledge-spillover event to another over time. For New York, around 100 individuals attended at least one of around 50 technology-focused Meetup events in 2005; in 2019, almost 35,000 individuals attended at least one of over 9,000 technology-focused events. Despite the growth in attendances at technology Meetups, the median event size remains around 10 to 20 participants for New York and less than 10 for Los Angeles throughout our observed time period, which would allow easy face-to-face interactions among event participants (see Fig. 3d).

Fig. 3 shows trends of an increasing number of technologists attending knowledge spillover events of increasing diversity in the mix of specialized knowledge and knowhow. The growth rate in members is notably higher for NYC compared to LA, and fewer attendees attend knowledge spillover events in Los Angeles compared to NYC.

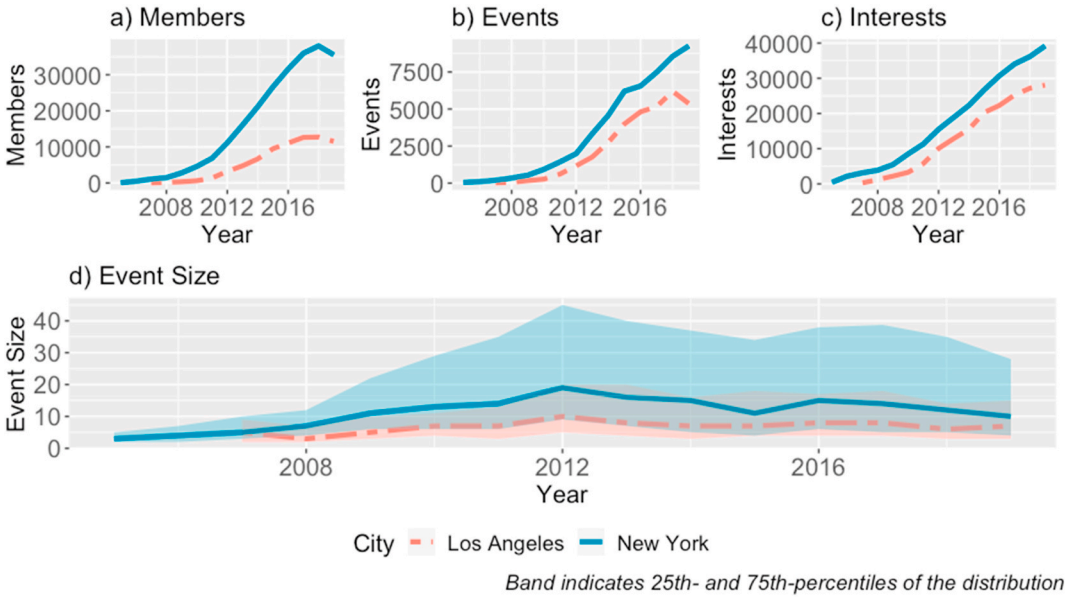

Fig. 3. Summary of growth trajectories of tech communities on Meetup.com in terms of a) members, b) technology-focused groups, and c) interests embodied by members. Size of technology Meetup events d) has held steady for most of the time period.

3.1. Representing interactions among technologists as knowledge networks

We can visualize Meetup-based social interactions among these community members as knowledge clusters, where every node represents an individual person and edges connect individuals who have co-attended a Meetup event, each of which was organized around a distinctive theme. We use time-stamped event RSVP's to identify potential face-to-face interactions between actors who co-attended at least one event in a given year. For each year, the cluster consists of a network of individuals (nodes) and their event-based interactions. The edges between people are weighted according to *how many* events they have co-attended—thus distinguishing between stronger and weaker connections in a local network. An edge is weighted by the cosine similarity between the two individuals from the TF-IDF (term frequency-inverse document frequency) weightings of the incidence matrix for each network.[19]

The more events two participants have in common, the stronger their edge weight and the greater the potential for knowledge exchange, as they are more likely to recognize each other from co-attendance at previous events and to have shared interests that motivate a mutually beneficial social exchange. They are also more likely to share a larger body of knowledge accumulated from common exposure to formal presentations and informal conversations at previous events. Rewiring is captured as changes in this network representation in the knowledge cluster over time, with the formation of new edges and the breaking of old ones. Technologists and entrepreneurs who explore outside of their local networks will get connected to more individuals over time as they reposition themselves.

Fig. 4 shows a 10% sample of each of the knowledge clusters for New York and Los Angeles. The sizes of the nodes represent the degree of connectivity, where larger nodes are those with the most connections. Likewise, the thickness of the edges represents the edge weight given to the connection between two nodes. Although all of our analyses use the full data set, the sampled networks give clear visual representations of the network dynamics. Intuitively, the subsample networks show only the strongest connections between a random 10% of individuals out of the entire network. Every node is colored by the year when the member first entered the network. It is immediately apparent from the sample visualizations that the tech communities have grown considerably since their inception, both in the number of people and the complexity of the social network. The over-time visualization presents discrete phases of morphogenesis of this economic institution of the knowledge economy, from a small undifferentiated cross-cutting blastocyst-like innovation cluster to a complex developed community ecology. Significantly, there is strong evidence for high levels of turnover from one year to the next. The compositional difference of members in the tech communities can have deeper implications on the types of knowledge being embodied and shared in the community ecology over time. We discuss the composition of the network and the kinds of knowledge embodied in the following section.

[19] Cosine similarity assigns greater weight to a relationship as the number of co-attended events increases. TF-IDF assigns less weight to co-attendance as the overall attendance increases, such that an event attended by every individual would not contribute to the weight of any of the edges. TF-IDF weightings are commonly used in text-based analysis to identity keywords that describe a particular text. The combination of TF-IDF and cosine similarity to construct two-mode networks has also been previously explored in social science research (e.g., Hoberg and Phillips 2016; Hoffman 2019). As a robustness check, we also weighted edges using the Jaccard distance; the findings were qualitatively consistent with the TF-IDF adjusted cosine similarity weightings. The metrics are explained in more detail in the Appendix.

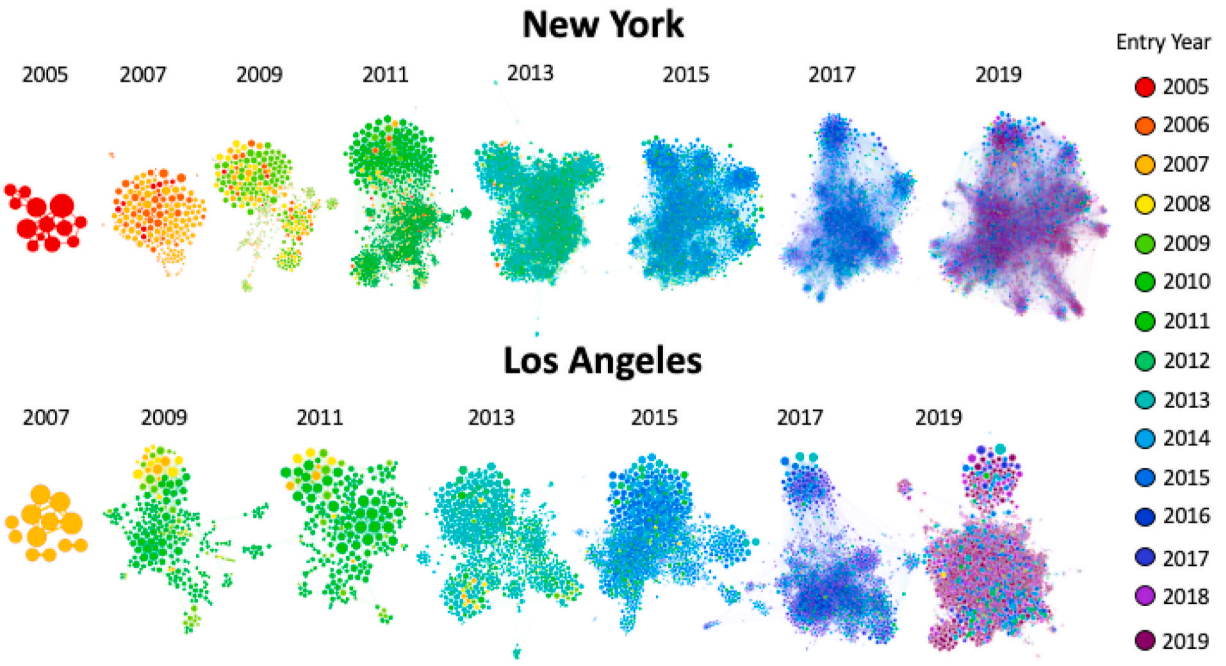

Fig. 4. Visualizations of a 10% random sample of the New York and Los Angeles technology community member networks on Meetup.com.

3.2. *Measuring specialized knowledge through affiliated interest terms*

We infer an opportunity for spillover of specialized knowledge and knowhow when individuals with different knowledge profiles interact through one of the Meetup events they mutually attend. Although individuals with similar profiles cooperate in knowledge sharing, we assume the discovery of a novel combination and recombination is more likely when individuals with different knowledge profiles come upon knowledge spillover. We measure specialized knowledge in the event attendance networks using topics that individuals report as their interests as well as the topics used to categorize their groups on Meetup.com. Anyone on Meetup.com can express their particular interests in one of two ways: by directly listing keywords that reflect an interest or by joining a Meetup group on a certain topic. Members are motivated to list their interests to more easily connect with other members who share similar interests. In our technology-oriented context, these profiles often list various technology-related topics such as software development, entrepreneurship, AI, or blockchain. Because interests are self-reported and listing them is not required, individuals can underreport their interests. In order to supplement the self-reported data, we also collected topics related to an individual's memberships in groups. Groups play a central role in facilitating connections on the Meetup.com platform. Individuals may be organizers of the groups themselves, which dictate that they be a member of that group, and certain events are only available to members of particular groups. Since Meetup groups are usually organized around a common theme, the combination of groups that an individual joins similarly reflects his or her interests. Both self-reported interests and topic tags associated with Meetup groups are henceforth collectively referred to as *interest terms*.[20]

3.3. *Measuring rewiring through changes in event attendances*

Over time, an individual may choose to become less active in certain types of knowledge cluster events but more involved in others, which leads to accompanying changes in social encounters and networks. We use these changes in network interactions to detect behavioral traces of rewiring. Rewiring allows individuals to explore a more diverse pool of knowledge or to exploit existing network connections for more depth of knowledge. We constructed our measure of an individual's level of rewiring at the event level from year to year by comparing the groups that host the events that individual attended one year with those that hosted the events the individual had attended the previous year. Intuitively, this measure can be interpreted as how "novel" the events are that an individual attends in one year compared to the ones attended in the previous year. By changing their event attendances, individuals consequently rewire their local networks as they branch out and explore other events and meet new people in overlapping clusters of the knowledge economy. By reaching out and exploring different knowledge spillover events sponsored by different groups, technologists and entrepreneurs take part in weaving the morphology that form the knowledge economy's organizational field.

[20] As the number of people and organizations involved in the community ecology increases, so does the number of interest terms present in the knowledge economy (Fig. 3c).

To calculate our rewiring measure, we first represent every individual's group event attendance in year t as a vector, $\boldsymbol{x}_t$, of size K, where K is the total number of technology Meetup groups. Each element $x_t^{(k)}$ corresponds to the count of events that the individual has attended in year t hosted by Meetup group k. We calculate the *novelty score* of an individual in year t as 1 minus the cosine distance between the individual's attendance vector in year t and the attendance vector in year $t-1$. This is formally stated in Equation (1).

$$Novelty_{it} = 1 - \frac{\boldsymbol{x}_{it}^T \boldsymbol{x}_{i,t-1}}{\|\boldsymbol{x}_{it}\| \|\boldsymbol{x}_{i,t-1}\|} \tag{1}$$

At one extreme, if individuals choose to attend events hosted by the same groups in the same proportions year after year, then their novelty score would be 0 every year. At the other extreme, if individuals rewire to explore the evolving knowledge economy and attend only events hosted by groups that did not host any of the events they attended in the previous year, they would be given a novelty score of 1 for that year.

Fig. 5 shows the distribution of (a) the event novelty rewiring score over time and (b) the average number of events that members attend, over time. Since our novelty measure is agnostic as to whether the difference in attendance behavior comes from attending new events (more attendances over time), breaking from old events (fewer attendances), or a mixture of both, we examine the trend of total events attended by members over time. We see from Fig. 5b that the number of events members attend has generally held steady in New York and Los Angeles. High levels of novelty in the later years seen in Fig. 5a are attributed to at least some degree of exploration outside of their existing networks, which involves both making new relationships and drifting away from old ones, while maintaining about the same intensity of event participation each year. We see from the novelty scores that there is an aggregate trend towards more exploration (and drifting or parting from old ties) over time as the regional technology networks grow in size and complexity. Actors who reach out to events hosted by new groups may be exploring opportunities for new knowledge and knowhow that might form the basis for innovation.

3.4. Access to diverse knowledge promotes repeated engagements

To the extent that discovery of innovation depends on access to new combinations and recombinations of knowledge and knowhow, we expect greater access to opportunity for knowledge spillover to be a motivator for exploration. We assume the odds of an actor meeting a like-minded alter whose ideas or knowhow the actor perceives as valuable for new combinations leading to innovation is higher when there is a variety of attendee interests at a knowledge spillover event. A greater access to a variety of knowledge and knowhow among attendees would likely be the appeal of NY Tech Meetup's monthly meetings where nearly 800 technologists, entrepreneurs, and venture capitalists assemble to listen to ten or so startup teams pitch novel ideas and business models. Furthermore, our assumption that diversity of accessible knowledge is appealing for entrepreneurs is reasonable given that the most commonly reported relationships among business contacts involve access to knowledge and knowhow outside of the entrepreneur's own abilities (e.g., collaborating on a new idea, advice and mentoring, introduction to new market segments). These results all suggest that the more diverse the interests that are embodied by acquaintances at a face-to-face meeting, the more likely it is for an entrepreneur to secure a valued collaboration (see Fig. 3).

We measured an actor's initial opportunity for social interaction involving knowledge spillover as the diversity of interests represented by all attendees at the first event and the extent of the actor's repeated social exchange as the number of subsequent events that they attend. The interest terms of every individual aggregate as the set of all interest terms associated with attendees at any

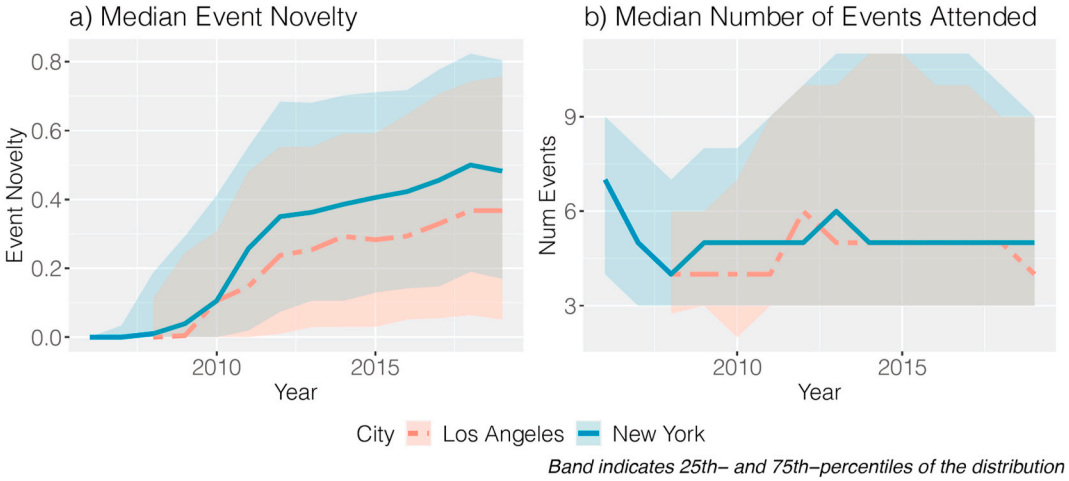

Fig. 5. Aggregate trend of rewiring at the event level. The aggregate level of event novelty increases over time, though the number of events attended by each person holds steady. In other words, the events they attend are changing from year to year as they explore outside their existing networks.

Meetup event, as a measure of the specialized knowledge that any event attendee has the opportunity to encounter. For every member in the New York or Los Angeles tech network, we identified the first technology Meetup event that the member attended and measured the diversity of interests that were represented by the attendees at that event. We then constructed a model to predict the total number of events that members attended throughout their tenure in the network as a function of the diversity of knowledge within their first event, controlling for when the event was held and the overall attendance at that event. Formally, we fit the Poisson regression model for count data with overdispersion given by Equation (2), where $TotalEventsAttended_i$ is the total number of events that member i has attended since entering the network, $EventYear_i$ is the year of the first event that member i attended, and $NumInterests_i$ is the total number of interests represented by all attendees at member i's first event.

$$E(TotalEventsAttended_i) = \mu_i;\ Var(TotalEventsAttended_i) = \phi\mu_i$$

$$\log(\mu_i) = \beta_0 + \beta_1 \log(NumInterests_i) + \beta_2 EventYear_i + \beta_3 \log(Attendees_i) \tag{2}$$

Table 1 shows the coefficient estimates for the parameters of the fitted model. The number of interests at the member's first event is positively correlated, indicating that the more diverse interests that were available at a member's first event, the more events that member is expected to attend in the future, even after controlling for the time and size of the first event. In New York, an increase of 1% in the number of interests represented at a member's first attendance is associated with a 25% increase in the number of expected event attendances. In Los Angeles, an increase of 1% in the number of unique interests represented is associated with a 12% increase in the number of expected event attendances.

This positive association in both metropolitan regions is consistent with what we would expect: Over time individuals are drawn to meetup events that might increase the odds for chance encounter with a new and potentially valuable combination or recombination of existing knowledge and knowhow.

3.5. Rewiring accounts for more integrated structure in the knowledge network

In an emerging knowledge economy, entrepreneurial actors reach out from their immediate networks to broaden their range of acquaintances in the community, increasing the likelihood for discovery of useful knowledge and knowhow. Evidence from surveys of founders of technology startups shows that a sizeable proportion of business contacts are a result of attendance at Meetup events, which often lead to collaboration, mentorship and connections with business partners within the community (see Fig. 1). These trends suggests that the entrepreneurs tend to derive the most value from exploring new and unfamiliar ideas, knowhow and expertise through these knowledge exchange events.

If entrepreneurs rewire to position themselves in a way that facilitates access to diverse knowledge, rewiring tends to move these actors away from the periphery of the network and closer to the core. Centrally located entrepreneurial actors have more access to opportunities for social exchange with other like-minded acquaintances through fewer network neighbors. Rewiring can be measured as changes in event attendance behavior, and opportunity for a richer diversity of knowledge spillover can be measured as an actor's closeness centrality in the network. The more new meetup events an actor attends, the more likely that individual will be positioned in a central location with a higher volume of knowledge spillover and innovative activity. Alternatively, if entrepreneurs rewire away from events with more varied and general knowledge towards more specialized meetups, they will drift towards the periphery of the network as they rewire and form self-contained clusters over time. Our theory suggests the former scenario is more likely and thus predicts a positive correlation between how much an individual rewires and their access to valued knowledge with a more central network position.

We use weighted normalized closeness centrality of nodes in the member network as a measure of network position. Closeness centrality of a node x on the network $G(V,E)$, where V is the set of all nodes and E is the set of all edges, is defined as in Equation (3), where $d(x,y)$ is the shortest weighted distance between node x and node y.

$$CC(x) = \frac{|V| - 1}{\sum_{y \in V} d(x,y)} \tag{3}$$

Table 1
Poisson regression for the number of total events a member attends over his or her tenure in the network.

	Dependent variable:	
	Expected Number of Events Attended (log)	
	(1) New York	(2) Los Angeles
Num Interests (log)	0.245*** (0.022)	0.118*** (0.026)
Event Year	−0.199*** (0.004)	−0.199*** (0.006)
Num Attendees (log)	−0.168*** (0.015)	−0.039 (0.026)
Constant	402.412*** (8.258)	403.118*** (11.092)
Observations	128,145	44,900
Overdispersion	141.653	113.325

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

To compare across years, we rescaled the centralities of the population each year to have zero mean and unit standard deviation. We used event novelty as an indication of rewiring, as it measures the amount of exposure a member has with novel content. To make their coefficient estimates more interpretable, we standardized the event novelty measures by subtracting the mean and dividing by the standard deviation for each year, and we also controlled for the total number of acquaintances that every individual encounters (degree of the individual's node in the network), and the number of events the individual attends each year. The formal regression we fit to test our prediction for network centrality and rewiring is given by Equation (4).

$$Centrality_{it} = \beta_0 + \beta_1 Year_t + \beta_2 EventNovelty_{it} + \boldsymbol{\beta} Controls_{it} + \alpha_i + \varepsilon_{it} \quad (4)$$

We employed a panel regression model fitted to Equation (4) to explain variation in each individual's centrality, using year, extent of rewiring, individual-level fixed effects and the control variables. Table 2 shows the coefficient estimates for the panel model calculated using centrality values that incorporate TFIDF-cosine edge weightings into the distance between nodes. The estimates for both New York and Los Angeles suggest that, holding all else constant, an individual's centrality decreases every year that the individual stays in the network (−0.05 standard deviations in normalized centrality for New York and −0.06 standard deviations for Los Angeles). However, more rewiring is associated with higher centrality, indicative of exploration unlocking access to more varied sources of knowledge. For New York, a one standard deviation increase in event novelty is associated with a 0.06 standard deviation increase in normalized centrality, while in Los Angeles, a one standard deviation increase in event novelty is associated with a 0.05 increase in normalized centrality. Given that central network positions imply that most actors in the network are accessible through only a small number of acquaintance connections, this finding is consistent with the prediction that entrepreneurs rewire their relations in order to access the diverse knowledge clusters that fuel innovative activity. The greater the perceived payoff from knowledge spillover, the more likely established actors will rewire to position themselves in a way that allows access to more diverse knowledge, including reaching out to new entrants in the knowledge economy.

In the aggregate, we observe morphological trends of decreasing centrality over time of the average individual, consistent with the network-wide tendency towards modular communities. Nevertheless, individual actors who choose to explore beyond their immediate social networks rewire to be exposed to novel events and new acquaintances. Exploration through rewiring allows individuals to offset these network-wide tendencies; those with higher levels of rewiring show relatively higher levels of network centrality, effectively bridging between communities of diverse knowledge.

Access to diverse bits of knowledge presents an opportunity for individual-level innovative activity. At the cluster level, we can measure the aggregate level of interconnectedness between and within localized clusters of individuals using network modularity. DellaPosta and Nee's (2020) longitudinal study of email threads of technologists in the emergence of New York City's knowledge economy shows that social processes giving rise to specialization and diversification are complementary. Specialization at the individual and group levels does not lead to balkanization of specialized knowledge communities sealed off from one another; rather, it provides a foundation for integrating diverse knowledge and knowhow.

As the knowledge economy matures, heterogeneous preferences among a growing pool of members facilitate the formation of social boundaries of modular communities, while rewiring tends to integrate the network by creating bridge ties across modular communities. At the micro-level, as individuals select which events to pursue and which to forgo, they are individually exposed to more diverse interests through other individuals they encounter at their events. At the macro-level, this type of selection leads to more integrated knowledge clusters as rewiring and exploration provide bridges to new knowledge clusters that emerge as the network expands across economic institutions and organizations of the community ecology of a knowledge economy.

4. From the microfoundation to the emergence of the knowledge economy

The theory also has implications for the consequences of rewiring among individual technologists as mirrored by a concomitant trend among new technology firms. On the Meetup platform, we found that as new knowledge continues to be introduced into the network, technologists who attend knowledge spillover events gain greater access to complementary knowledge over time. This

Table 2
Coefficient estimates of a panel regression model for closeness centrality on time and event novelty rewiring measures. Significance is calculated using heteroskedasticity robust standard errors. For both New York and Los Angeles, rewiring is associated with greater centrality despite a network-wide tendency to shift to less central positions in the network.

	Dependent variable:	
	Closeness Centrality	
	(1) New York	(2) Los Angeles
Year	−0.052*** (0.002)	−0.061*** (0.005)
Event Novelty	0.057*** (0.004)	0.049*** (0.009)
Num Events Attended (log)	0.196*** (0.006)	0.050*** (0.014)
Num Network Connections (log)	0.432*** (0.007)	0.291*** (0.017)
Observations	88,683[a]	24,979[a]

*p < 0.05, **p < 0.01, ***p < 0.001.
[a] Some observations are omitted as event novelty requires a member to remain in the network for two or more consecutive years, and closeness centrality is only calculated for nodes in the largest connected component.

increased access is in large part a byproduct of rewiring, where an individual follows up on certain types of events with more intensity. While the knowledge network expands as a whole, rewiring can also expand local knowledge networks of individual technologists. On average, individuals are exposed to more types of knowledge over time and, through rewiring, this increased exposure leads to greater overlap in knowledge among technologists in the network, inhibiting the tendency towards balkanization as the network expands over time. We also know from the surveys conducted among entrepreneurs who attended events hosted by the New York Tech Meetup that knowledge sharing at these events founded innovative startup firms in the region.

Meetup.com is one of many economic institutions that can reflect growth and rewiring trends of the underlying regional knowledge network. Our theory focuses on social processes that comprise the microfoundation in the emergence of the knowledge economy. At the meso-level of the organizational field (Nee 2005: 56, 60–62), the knowledge economy simultaneously reflects a) the increase in growth and b) the increase in integration that we observe at the individual level, where individuals are exposed to more novel events over time. Fig. 5a reports evidence consistent with increased rewiring. Similar trends can be observed in a separate but related context that more directly reflects innovative outcomes in the knowledge economy. When individuals are connected with a broader range of knowledge and ideas, the likelihood increases that one of these encounters results in an innovation that matures into a technology startup firm. Technology startups require innovation leading to new, and possibly more diverse and complex, knowledge. We thus expect a downstream effect where the startups that are founded as a result of innovation reflect the tendency for ties to form that span across multiple knowledge clusters. More access to diverse knowledge at the individual level can thus lead to more industry-spanning and more overlap in new startup firms. Therefore, broadening of the scope of knowledge and the increase in overlapping knowledge clusters are not only limited to knowledge workers but are also reflected in startup technology firms as well. Over time, we expect newer startup firms to span more industries, and also the overlap in industries between startups to increase in each regional knowledge economy.

The trends show the effect of the burst of the dotcom bubble in 2000, followed by a brief interlude of declining technology-enabled firms in both cities.[21] After the founding of Meetup.com and the NY Tech Meetup in 2002, Fig. 6 shows a cumulative rebirth of entrepreneurial action in founding new tech firms at the start of the new millennium. The period between 2005 and 2012 shows the largest increase in the number of technology startups founded in both New York and Los Angeles. The growth of the regional knowledge economy paradoxically accelerates from 2008 to 2013 despite the severity of a nationwide economic crisis and the collapse of investment banks in New York City. Forty-seven industries are represented in our set of all technology startups; the most common industries are software, internet services, information technology, and media and entertainment.[22] The rate of growth in New York is greater than that in Los Angeles, which may be attributed to greater intensity of knowledge spillover in a New York urban ecology that is more favorable for face-to-face interactions among technologists. The founding rate of technology startups steadily declined following the 2014 peak, suggesting a density dependent trend (Hannan and Freeman 1989).

Fig. 7a shows the average number of industries listed per startup firm over time. Firms founded in later years tend to be classified under more industries than firms that were founded earlier. Because the total set of industries did not change much between 2000 and 2019, in both New York and Los Angeles, it is reasonable to infer that the increasing trend in industry tags per firm is a consequence of firms increasingly incorporating aspects of multiple industries. Even though the pool of industrial categories has remained fairly constant over time, the complexity (spanning multiple traditional industries) of the startups has steadily increased. The increase in the degree of industry-spanning by technology startups mirrors the observations for Meetup technologists; the average number of interests per technologist steadily increases over time as the knowledge network expanded to incorporate new interests and ideas. Similarly, the average number of industries that any particular startup spans has also increased. This finding is consistent with the prediction that startups founded amid a more developed knowledge economy will span more industries.

Fig. 7b shows the change over time in industry overlap among startup firms. Overlap is measured as the probability two randomly chosen startups founded in a given year share at least one industry label. As each newly founded startup spans an increasing number of categories, the probability of overlap between any two startups also increases, reflecting a similar trend that is observed for Meetup technologists. The results suggest that amid the two regional technology economies, knowledge entrepreneurs and workers are individually exposed to more topics and ideas through ongoing rewiring that integrates different parts of the knowledge network. This simultaneous growth and integration of knowledge clusters at the individual level is a reflection of changes in the broader technology economy, with similar social dynamics observed in technology startup firms in both regions. Consistent with our theory, technology startups span an increasing number of industry categories over time (growth), which also contributes to an increase in the degree of overlap among new technology startup industries (integration).

5. Conclusion

We proffer a positive theory and explanation-sketch detailing knowledge spillover, network rewiring, and innovation as causal mechanisms enabling and guiding the social dynamics of emergence of a regional knowledge economy. Evidence from a two-wave

[21] Using the business data aggregator Crunchbase, we collected supplemental data on technology startup firms that were founded in New York and in Los Angeles between 2000 and 2019.

[22] Almost every industry is represented by at least one new startup each year between 2000 and 2019 in both New York and Los Angeles; thus, unlike interest topics on Meetup.com, there does not appear to be an influx of industry category labels from the Crunchbase data. A firm can be classified under multiple industry labels. Out of the Crunchbase sample of technology firms founded between 2000 and 2019 in New York and Los Angeles, the number of industries listed for a firm ranges from 1 to 16.

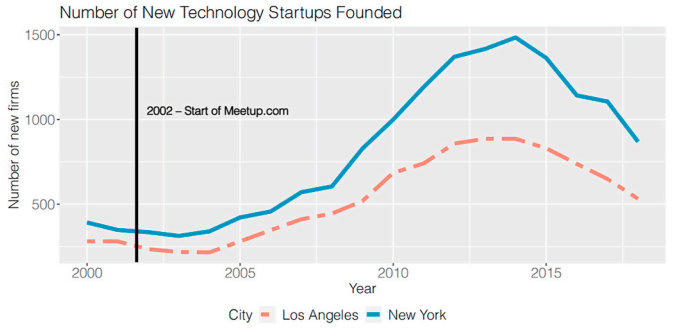

Fig. 6. The number of new technology startups founded over time in New York (blue) and Los Angeles (red), according to Crunchbase. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

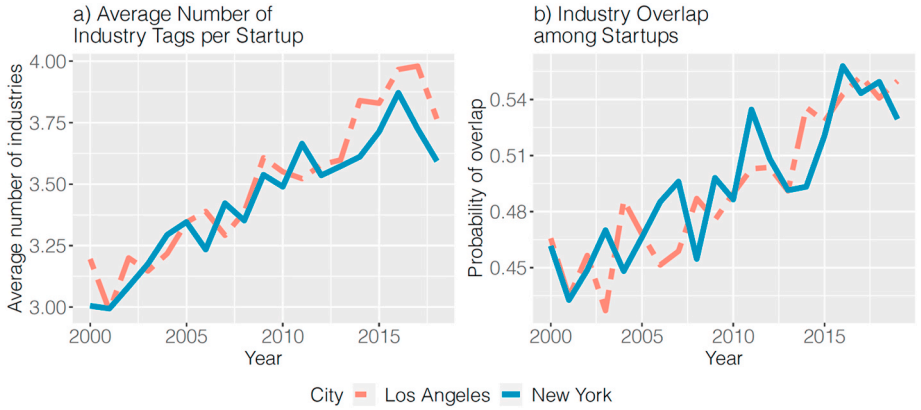

Fig. 7. (a) The average number of industries listed per startup firm over time reported by Crunchbase. In addition to more firms being founded, especially around 2010 to 2015, new firms tend to span more and more industry categories. (b) The increase over time in the probability of randomly selecting two startups that are in the same industry.

survey of tech entrepreneurs and field research in New York City substantiates a link between co-attendance at Meetup events, knowledge spillover, network rewiring and innovation. Using digital records, we traced the formation and evolution of meetup knowledge clusters as they rapidly expanded in size and complexity, alongside a concomitant rapid growth in the founding of startup firms in New York and Los Angeles and the size of linked knowledge clusters.

The regional knowledge economies in New York and Los Angeles have seen tremendous growth reflected in the rate of founding of technology-focused startup firms in both New York and Los Angeles during this period. Despite the geographical differences of New York and Los Angeles, the knowledge networks for both regions grew in both size and complexity, from a small undifferentiated seed cluster to a vast assemblage of overlapping knowledge clusters with more defined but distinct modular structures. In both knowledge economies, new types of knowledge are more resonant with newer members. New York City's advantage, however, is evident in a substantially larger number of technologists and greater diversity of Meetup events and interests. This advantage enabled a rapid emergence as the second largest regional knowledge economy in the United States.

As the knowledge networks evolve, new interests are continually introduced along with new participants in the regional knowledge economy. Despite high levels of turnover, these interests persist as they are ultimately adopted by individuals who remain in the network. The growth of each regional knowledge network is accompanied by the tendency for network structures to become less centralized, less specialized and more modular. However, consistent with our proposed mechanisms—knowledge spillover and network rewiring—certain individuals continue to explore beyond their local networks, and as a result, this behavior offsets some of the network-wide tendencies. Repeat social interactions in overlapping networks enable and motivate cooperation, trust and shared group identity manifest in prosocial behavior in the knowledge economy. Those who are engaged in more exploration, or rewiring, of their local networks tend to remain more centrally positioned and are exposed to a more representative set of interests in the network. At the macro-level, the presence of rewiring diminishes the extent of modularity and contributes to more integration among modular components in the network.

The story of emergence of these regional knowledge networks is ultimately one of growing size, complexity, and overlap. At the aggregate level, the knowledge clusters expand in size and become more specialized and modular; however, at the individual level, continued exploration and network rewiring contributes to more overlap among individuals in terms of shared knowledge. This trend is evident not only on the Meetup.com platform but is also mirrored by the broader technology economy through innovative outcomes

such as technology startups. Technology startups founded during the same time period as in our Meetup analyses increasingly span more industries and exhibit a greater degree of industry overlap. Taken together, these two concomitant trends reflect the emergence of an organizational field embedded in cross-cutting, overlapping networks in each regional knowledge economy.

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References

Baldassarri, Delia, 2015. Cooperative networks: altruism, group solidarity, reciprocity, and sanctioning in Ugandan producer organizations. Am. J. Sociol. 121, 355–395.
Bol, Thijs, de Vaan, Mathijs, Arnout van de Rijt, 2018. The Matthew Effect in Science Funding. Proceeding of the National Academy of Sciences. https://doi.org/10.1073/pnas.171955711.
Coleman, James S., 1988. Social capital in the creation of human capital. Am. J. Sociol. 94, S95–S120.
Cometto, Maria Teresa, Piol, Alessandro, 2013. Tech and the City: the Making of New York's Startup Community. Mirandola Press, New York.
DellaPosta, Daniel, Nee, Victor, 2020. Emergence of diverse and specialized knowledge in a metropolitan tech cluster. Soc. Sci. Res. https://doi.org/10.1016/j.ssresearch.2019.102377.
Glaeser, Edward L., 1999. Learning in cities. J. Urban Econ. 4, 351–370.
Glaeser, Edward L., 2008. Cities, Agglomeration and Spatial Equilibrium. Oxford University Press, Oxford.
Glaeser, Edward L., 2011. The Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier. Penguin Press, New York.
Hannan, Michael T., Freeman, John, 1989. Organizational Ecology. Harvard University Press, Cambridge, MA.
Hempel, Carl G., Oppenheim, 1948. The logic of explanation. Philos. Sci. 15 (2), 135–175.
Hoberg, Gerald, Phillips, Gordon M., 2016. Text-based network industries and endogenous product differentiation. J. Polit. Econ. 124, 1423–1465.
Hoffman, Mark Anthony, 2019. The materiality of ideology: cultural consumption and political thought after the American revolution. Am. J. Sociol. 125, 1–62.
Hofman, Jake, M., Amit Sharman, Duncan, J. Watts., 2017. Prediction and Explanation in Social Systems. Science 355, 486–488.
Homans, George C., 1974. Social Behavior: Its Elementary Forms. Harcourt, Brace Jovanovich, Inc, New York.
Jacobs, Jane, 1984. Cities and the Wealth of Nations: Principles of Economic Life. Cambridge University Press, Cambridge.
March, James A., 2010. The Ambiguities of Experience. Cornell University Press, Ithaca, NY.
Marshall, Alfred, 1920. Principles of Economics, eighth ed., vol. 1890. Porcupine Press, Philadelphia.
Merton, Robert K., 1968a. Social Theory and Social Structure. Free Press, New York.
Merton, Robert K., 1968b. The Matthew effect in science. Science 159, 56–63.
Mokyr, Joel, 2002. The Gifts of Athena: Historical Origins of the Knowledge Economy. Princeton University Press, Princeton and Oxford.
Mokyr, Joel, 2010. Entrepreneurship and the industrial revolution in Britain. In: *The Invention Of Enterprise*, D.S. Landes. J. Mokyr, & W.J. Baumol. Princeton University Press, Princeton and Oxford, pp. 183–210.
Moretti, Enrico, 2012. The New Geography of Jobs. Houghton Mifflin Harcourt, New York.
Nee, Victor, 2005. The new institutionalisms in economics and sociology. In: *The Handbook Of Economic Sociology*, NJ Smelser and R Swedberg. Princeton University Press and Russell Sage Foundation, Princeton, pp. 49–74.
Nee, Victor, Drouhot, Lucas, 2020. Immigration, opportunity, and assimilation in a technology economy. Theor. Soc. https://doi.org/10.1007/s11186-020-09414-0.
Nee, Victor, Opper, Sonja, 2012. Capitalism from below: Markets and Institutional Change in China. Harvard University Press, Cambridge, MA.
Nee, Victor, Paul, Ingram, 1998. Embeddedness and beyond: institutions, exchange and social structure. In: Brinton, M.C., Nee, V. (Eds.), The New Institutionalism in Sociology. Russell Sage Foundation, New York, pp. 19–45.
Nowak, Martin A., 2006. Five rules for the evolution of cooperation. Science 314, 1561.
Nowak, Martin A., Karl, Sigmund, 1998. Evolution of indirect reciprocity by image scoring. Nature 339, 573–577.
Owen-Smith, Jason, Powell, Walter W., 2004. Knowledge networks as channels and conduits: the effects of spillovers in the boston biotechnology community. Organ. Sci. 15, 5–21.
Padgett, John F., 2012. Transposition and Refunctionality: the Birth of Partnership Systems in Renaissance Florence. In: John Padgett, and Walter Powell Edited, the Emergence of Organizations and Markets. Princeton University Press, Princeton, pp. 168–207.
Padgett, John F., Ansell, Christopher K., 1993. Robust action and the rise of the medici, 1400-1434. Am. J. Sociol. 98, 1259–1319.
Padgett, John F., Powell, Walter W., 2012. The Emergence of Organizations and Markets. Princeton University Press, Princeton.
Powell, Walter W., 1990. Neither market nor hierarchy: network forms of organizationa. Res. Organ. Behav. 12 (2), 295–336.
Powell, Walter W., White, Douglas R., Koput, Kenneth W., Owen-Smith, Jason, 2005. Network dynamics and field evolution: the growth of interorganizational collaboration in the life sciences. Am. J. Sociol. 110, 1132–1205.
Saxenian, Annalee, 1994. Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Harvard University Press, Cambridge, MA.
Saxenian, Annalee, 2006. The New Argonauts: Regional Advantage in a Global Economy. Harvard University Press, Cambridge, MA.
Schumpeter, Joseph A., 1934. The Theory of Economic Development. Harvard University Press, Cambridge, MA.
Simon, Herbert A., 1957. Models of Man. John Wiley & Sons, Hoboken, New Jerey.
Simon, Herbert A., 1972. "Theories of Bounded Rationality." *Decision and Organization*. In: McGuire, C.B., Roy Radner (Eds.). Amsterdam and London: North-Holland Publishing Co.
Simon, Herbert A., 1978. "Rationality as process and as product of thought.". Am. Econ. Rev. 68 (2), 1–16.
Simon, Herbert A., 1991. "Bounded rationality and organizational learning.". Organ. Sci. https://doi.org/10.1287/orsc.2.1.125.
Stigler, George, J., 1991. Charles babbage (1791 + 200 = 1991). J. Econ. Lit. 29, 1149–1152.
Storper, Michael, 1997. The Regional World: Territorial Development in a Global Economy. Guilford Press, New York.
Storper, Michael, 2011. Keys to the City: How Economics, Institutions, Social Interactions, and Politics Shape Development. Princeton University Press, Princeton.
Storper, Michael, Kemeny, Thomas, Makarem, Naii, Osman, Taner, 2015. The Rise and Fall of Urban Economies: Lessons from San Francisco and Los Angeles. Stanford University Press, Stanford.
Uzzi, Brian, 1996. The sources and consequences of embeddedness for the economic performance of organizations: the network effect. Am. Socio. Rev. 61, 674–698.

Van de Rijt, Arnout, Kang, Soong Moon, Restivo, Michael, Patil, Akshay, 2014. Field experiments of successs-breeds-success dynamics. Proc. Natl. Acad. Sci. USA. https://doi.org/10.1073/pnas.13168361.

Zukin, Sharon, 2020. The Innovation Complex: Cities, Tech, and the New Economy. Oxford University Press, New York.

Tomasello, Michael, Alicia P. Melis, Claudio Tennie, Emily Wyman and Esther Herrman. 2012. "Two key steps in the evolution of human cooperation: the interdependence hypothesis." *Curr. Anthropol.* 53(6): 673-692.