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Scaling Ostrom: Diffusion Patterns of Institutions for Collective Action

Michal Shur-Ofry[ϒ], Noa Dadon-Raveh[¥], Ofer Malcai[±]

Abstract

Informal institutions for collective action (ICAs) are bottom-up collaborations through which communities address shared challenges. Economist Elinor Ostrom famously identified ICAs as a potential solution to collective action problems, alongside the traditional approaches of top-down regulation and privatization.

Yet, ICAs are often regarded as limited solutions to macro-level problems due to their inherently local scale. We challenge this view by demonstrating that ICAs can scale through self-organized diffusion, following predictable patterns observed in complex systems.

Analyzing four case studies—food co-ops, community gardens, collaborative Holocaust commemoration events, and Pride parades—we find that ICA diffusion exhibits exponential temporal growth fitting the Bass diffusion model, and spatial clustering patterns, providing empirical evidence of social contagion among ICAs. Such "scaling through contagion" allows ICAs to maintain adaptability to local context while generating macro-level impact.

The complex systems perspective we apply reveals that ICAs' potential as policy tools for addressing macro-scale collective action challenges is more significant than previously recognized. We discuss how policymakers can leverage these predictable diffusion dynamics through strategic, low-cost interventions that we term "self-expanding nudges" to steer and amplify grassroots solutions and more effectively address societal challenges.

Keywords: Institutions for collective action; diffusion of innovation; social contagion; complex systems; commons governance; innovation policy

ϒ Hebrew University of Jerusalem; NYU Information Law Institute.

¥ Hebrew University of Jerusalem.

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1. Introduction

The problem of collective action has been one of the most fundamental puzzles in political economy and legal theory during the past decades. The problem, in a nutshell, concerns the difficulty of groups of people to collaborate in the pursuit of a common goal, given the self-interested behavior of individuals (Hardin, 1968; Guttman, 1978; Dawes et al., 1986; Ostrom, 1990). One prominent manifestation of this problem, famously labeled the "tragedy of the commons", concerns the challenge of managing common resources in an efficient way that avoids free-riding and excessive consumption (Hardin, 1968; Dawes et al., 1986). Other collective action challenges concern socially beneficial projects that are non-excludable. Such cases raise 'free riding' concerns, since it is hard to limit the benefits generated only to those who contributed to the effort (e.g., Olson, 1965). The production of innovative technologies, the adoption of environmentally responsible behavior, or the vaccination of a sufficiently large segment of the population to create herd-immunity are all cases in point.

The traditional approaches to solving problems of collective action, described in a vast body of literature, identified two solutions: top-down intervention in the form of legal regulation (e.g., limiting the use-time of a park to avoid erosion of the resource), or private property allocation (e.g., dividing the land into private parcels, or allocating private patent rights to incentivize new technologies) (e.g., Hardin, 1968; Frischmann, Madison & Strandburg, 2010). However, toward the end of the twentieth century, economist Elinor Ostrom challenged this binary view and demonstrated that individuals can effectively address collective action problems through bottom-up, informal, collaborations, which she termed "institutions for collective action" (ICAs) (Ostrom, 1990). Ostrom's work awarded her the Nobel Prize in economics in 2011, and was followed by numerous studies of ICAs–also labeled "commons governance schemes"–in different domains, including land use, environment, and urban planning (e.g., McKean & Ostrom, 1995; Lehavi, 2008; Foster, 2011; Feldman & Perez, 2012; Foster, 2016).

A related strand of studies has also been using Ostrom's framework to investigate "knowledge commons", namely informal collaborations in the production and use of cultural, intellectual, and technological resources (e.g., Ostrom & Hess, 2007; Frischmann, Madison & Strandburg, 2010; Frischmann, Madison & Strandburg, 2018). Some of those studies have shown that at times, ICAs generate more efficient outcomes relative to the more traditional scheme of top-down regulation, because they are better aligned with the local conditions and the specific needs of the affected populations (Ellickson, 1998; Foster, 2006; Di Robilant, 2014; Rennie & Potts, 2024).

However, most of the ICAs studied in the literature were restricted to a relatively small number of participants. Ostrom herself noted that her work focused on small-scale resources affecting limited numbers of people, ranging between fifty and fifteen-thousand (McGinnis & Ostrom, 2008). This limitation seems intuitive: A very large number of people in an informal collaboration can jeopardize coordination, increase the risks of free riding, and undermine the advantages of alignment with local needs and conditions (cf., Fukuyama, 2001, p. 490). As a result, a major critique raised against ICAs maintains that these collaborations are inherently restricted to a small, local scale, and have only slight significance as a policy tool for handling broader issues relating to the grand, macro-level, societal challenges. Addressing the question of scale is therefore one of the most pressing desiderata for any policymaking concerned with solutions to collective action problems. As Frischmann et al. note:

> "[n]ow, more than ever, we need to explore if, when, and how commons governance can scale" (Frischmann, Madison & Strandburg, 2018, p. 1240).

In this research we propose a new way to meet the challenge of scaling commons governance. We locate the spread of ICAs within the broader scheme of self-organized diffusion that emerges in complex systems. We hypothesize that ICAs can spread from the micro to the macro level through self-organization, in accordance with diffusion dynamics that are well recognized in many complex systems, where *typical temporal and spatial patterns* at the macro-level arise out of local interactions amid the components comprising the system at the micro-level. Put simply, we suggest that the scaling of institutions for collective action does *not* necessitate a large number of members joining a single collaboration. Rather, ICAs can scale through social contagion, by “giving birth” to additional ICAs, resulting in a network of ICAs that grows in accordance with predictable patterns. This type of growth allows ICAs to maintain the advantages of the local scale and concomitantly generate a macro-level effect.

In order to explore this hypothesis, we analyze four case studies of ICAs’ diffusion:

1) Food co-ops diffusing across the United States;

2) Community gardens diffusing in an urban space;

3) Collaborative Holocaust commemoration practices known as “Memory in the Living Room” (MIL), diffusing across Israel; and

4) Pride Parades diffusing globally.

We begin with a short description of each of these case studies, and explore whether they display the internal hallmarks of ICAs in the Ostrom sense. We focus on the principal traits identified by Ostrom, primarily: (1) that participants initiate the collaboration in a bottom-up way; (2) that the members devise the institution’s rules of operation and develop informal mechanisms for adapting decisions and for resolving disputes, and (3) that the institutions are context-sensitive and reflect the needs of the local community (Ostrom, 1990). We also detail the sources of the data we collected about these collaborations,

We then empirically trace the diffusion of each of these ICAs, using methods commonly employed in the study of complex systems. In so doing, we draw on extensive research in complex systems science, establishing that self-organized diffusion that is influenced by social interactions follows consistent *patterns* across time and space. These patterns include an exponential *temporal* diffusion curve (Rogers, 2003; Bass, 1969) and a *spatial* structure characterized by *clusters*—groups whose members are more connected to each other than to the rest of the network (e.g., Bak et al. 1998; Watts & Strogatz, 1998). These properties are so pervasive that their presence is considered a "signature of self-organization" and a strong indication that a process of contagion–in our case, social contagion–occurred among the system's components—in our case, the ICAs (e.g., Bak et al. 1998; Batty, 2007; Ben-Jacob et al., 1995; Rogers, 2003).

2. ICA Properties

2.1 Food Co-ops

While the first known food co-operatives in the United States trace back to the 19th century, the vast majority of those early co-ops no longer exist. We therefore study the diffusion of two more recent waves of food co-ops in the United States during two distinct periods identified in the literature: a) between the years 1967 and 1993 ("the first wave"), and b) between the years 1994 and 2024 ("the second wave") (Steinman, 2019: 102-128).[1]

Studies exploring the properties and spread of food co-ops in North America describe them as "grassroot organizations" of people belonging to local communities, which are initiated, founded, and owned by the members of those communities (Knupfer, 2013, pp. 2-3, 9; Steinman, 2019; West & Berner, 2021; Young, 2023). The motivation for the establishment of food co-ops is often linked to social, economic, environmental, health, or educational values. The co-op members unite voluntarily to meet their common goals through a jointly owned enterprise, and shape the character and activities of the co-op accordingly (Knupfer, 2013, p. 3-4; Steinman, 2019, p. 103).

[1] Notably, while Steinman refers to the waves in broad term (such as "the 1960s", "the 1990s"), we draw the precise period of each of the waves from analyzing the temporal diffusion data, as explained in section 3.2 *infra*.

Because co-ops are entities whose establishment and operations involve financial stakes, the collaboration typically does have a formal manifestation in the co-op bylaws–unlike the ideal Ostrom framework. The bylaws specify the co-op's rules of operation, the decision-making mechanisms, the powers ascribed to the board of directors (elected by the members for specific terms, sometimes on a voluntary basis), and the topics that require decisions by the members themselves. Yet, unlike regular corporations, each member has an equal voting power (Knupfer, 2013, pp. 2-3; Steinman, 2019). In addition, the profits of food co-ops are typically circulated back into the co-op, or, in some cases, distributed among the members. As Jon Steinman, author and food co-ops activist described it in an interview "there's never any money being extracted out of the community".[2]

Relatedly, food co-ops are context sensitive and maintain a tight connection to the values and needs of the communities that build them. Different co-ops have diverse emphases, from vegetarian, to organic, to local supplies and more, and conduct different community events (e.g., cooking classes, activities for children, or other gatherings). As Steinman observes, "there's nothing cookie cutter" about food co-ops (Steinman, 2019: 133-137). This context sensitivity is a hallmark of ICAs.

Due to their tight links to the communities that build and operate them, food co-ops are perceived as more than just grocery stores, but rather as "community development organizations" (Co-ops Interview). Their diffusion across North America since the middle of the 20th century has been described as "an engine of political and economic transformation", and an evolution toward a grassroot "economic democracy" (Steinman, 2019, pp. 102-103; Knupfer, 2013, p. 2).

In all, in light of their grassroot nature, strong collaborative features and context sensitivity, and despite a certain deviation from the

[2] Interview with Jon Steinman, Feb 19, 2025 and subsequent correspondence, on-file with the authors ("Co-ops Interview").

"nominal" Ostrom framework, we propose that food co-ops fall within the scope of our inquiry of ICA diffusion.

In examining co-ops' diffusion we rely on a dataset comprising 380 co-ops in the United States, which were active between 2018 and 2024, provided by Jon Steinman.[3] The data include the co-ops' geographical locations, to which we added their respective opening dates (collected manually). Notably, this case study includes layered data pertaining to two long periods of time (the two waves), certain co-ops closed during the relevant periods, and there is some ambiguity as to the exact overall number of co-ops. We detail these limitations and explain our methodological choices in the Supplementary Materials.

2.2 Community Gardens

We study the diffusion of community gardens in the city of Jerusalem between the years 2000 and 2015. We rely on previous work by two of us, that included temporal and spatial diffusion data of the gardens provided by the city's municipality, an interview with the municipal coordinator of the community gardens ("Gardens' Interview") and various sources describing the Jerusalem community gardens (Shur-Ofry & Malcai, 2019).

Literature recognizes the establishment of community gardens is generally a bottom-up process that does not result from top-down regulatory decisions (e.g., Lehavi, 2008:189-190). The community gardens in Jerusalem follow this grassroot pattern. The gardens are initiated by the city's residents, who reach out to the municipality and request the allocation of a designated public area within their neighborhoods. The operation and maintenance of the gardens is carried out by community members and is subject to their discretion. Members establish the rules of operations for 'their' garden, deciding

[3] For the co-ops locations' data, see also Jon Steinmans' Food Co-op Finder, https://grocerystory.coop/food-co-op-directory. Note that, while the map covers co-ops in the US and Canada, our dataset included only co-ops in the United States. Respective opening dates were added after manual research.

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on the use of the lots, the working schedules, the crops to be cultivated, whether to host special events in the space, etc. Members also adopted their own enforcement and internal conflict resolution mechanisms, so that the vast majority of disputes are resolved internally and effectively (Shur-Ofry & Malcai, 2019; Gardens Interview).

In less than twenty years since the first community garden was established in Jerusalem, the number of gardens has grown to sixty-three, spanning neighborhoods across the entire city. The gardens are described as "a product of the location in which they emerge" (Gardens Interview). They vary in appearance, activities, the character of the local populations, and other respects, thus displaying the context-sensitivity characteristic of ICAs.

In a 2013 survey among community gardens' members, participants described the gardens as venues for social interactions, connection to the community, and even as "a second home". Participants further reported that their garden involvement increased their engagement in other community activities, improved their environmental awareness, and had a generally positive impact on their quality of life.[4]

Altogether, the bottom-up initiative, the informal rules of operations and dispute resolution mechanisms, and the adaptability to local communities, situate the Jerusalem community gardens within Ostrom's ICA framework.

2.3 Memory in the Living Room (MIL)

We examine the diffusion of a bottom-up Holocaust commemoration initiative known as "Memory in the Living Room" (MIL) across Israel between the years 2011 and 2020. We rely on temporal diffusion data provided to us by the MIL initiative, an interview we conducted with MIL's co-director ("MIL Interview"),[5] information provided on the

[4] "Survey of Community Gardens' Participants 2013", Aitek Forum for Community Cultivated Green Sites in Jerusalem, provided to the authors by the Jerusalem municipality, citation translated by the authors. For further details, see Shur-Ofry & Malcai, 2019.

[5] Interview with Michal Lippman, co-director of the non-profit MIL organization, June 20, 2024, on file with the authors ("MIL Interview"). All citations are translated by the authors.

MIL website, and previous academic work that explored the MIL initiative and its implications for the Holocaust's collective memory in Israel (Steir-Livny, 2020; Kook, 2021).

MIL was initiated in 2011. A young woman seeking an informal, participatory, way to commemorate the Holocaust decided to host forty guests in her private home, for a conversation with a Holocaust survivor followed by group deliberations and reflections. In the following year, most of those first participants hosted their own "MIL salons", each comprising dozens of participants. In subsequent years the initiative continued to spread widely and quickly through word of mouth (MIL Interview). Within ten years, thousands of MILs were formed across the different regions of the country, reaching an estimated one and a half million participants (MIL data; Kook, 2021).[6]

A particular MIL event bears the characteristic features of an ICA. Typically, it is a small, intimate gathering, taking place in a private home. Usually, the event begins with a testimony, and continues with an open discussion. Participants are urged to be active and engage in conversation and deliberation (Kook, 2021; MIL Interview). The MIL non-profit organization and the MIL website, created in response to the widespread growth of the initiative, connect potential participants with hosts and provide the latter with an "event kit". Yet, importantly, members of the community are free to design their own versions and events. As the MIL co-manager explains:

> "MIL is "open source"... no one will tell you what to do. Just like no one checks what kind of a Passover Seder you hold at home..[..]... We provide a suggestion for how an event could look, but it's absolutely not mandatory for anyone" (MIL Interview).

Research indicates that MIL transformed the commemorative landscape of the Holocaust in Israel–which had previously consisted mostly of top-down formal rituals initiated by the state, educational

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[6] This estimate is conservative, since some of the more recent MIL hosts carry out the MIL activity without approaching the MIL website or the initiative's organizers – see MIL Interview.

institutions, or local municipalities–and has been generating a lasting impact on the culture of Holocaust remembrance and its collective memory (Kook, 2021:972).

2.4 Pride Parades

Finally, as an example of self-organization of ICAs at the global scale, we examine the diffusion of Pride parades across the globe, from the Stonewall protests in 1969 to date. We rely on several studies that describe the Parades' history, traits, and diffusion (McFarland, 2016; Peterson et al., 2018:18-21; McLarren, 2022). We further collected data from multiple websites tracing the temporal diffusion of the parades across states in the United States and in countries across the globe.[7]

The first Pride marches took place in New York City, Los Angeles, Chicago and San Francisco in 1970, a year after the 1969 Stonewall riots, which followed a police raid on a gay bar in Greenwich Village (McLarren, 2022). Initiated by activists to commemorate the Stonewall uprising, and to protest discrimination and anti-gay violence, the parades combined political protest with celebratory elements, marking a pivotal moment in LGBTQ+ activism. The success of the first parades inspired activists in other cities to follow their lead. Parades spread geographically across the United States, reaching more than a hundred cities in the country within a period of forty years (McFarland, 2016:69).

Concomitantly, during the 1970s Pride events began to spread in Western Europe, in a process commonly linked to cultural changes that followed the 1968 social protests (Peterson et al., 2018). A second phase of international diffusion emerged during the 1980s, with the establishment of the US-dominated non-profit organization InterPride that introduced active efforts to promote parades in additional countries. These efforts were bolstered by the subsequent establishment of additional Pride organizations such as EuroPride (1992) and WorldPride (2000). By 2022, Pride events diffused to 110 countries worldwide (McLarren, 2022).

[7] For the list of websites, see Supplementary Materials.

During the process of global diffusion, conflicts occasionally emerged as to the form the events should take, sometimes reflecting tensions and divisions within the LGBTQ+ communities in different countries.[8i] Generally, these conflicts were resolved locally within the relevant community, resulting in considerable differences between the particular events.

More broadly, while local LGBTQ+ movements outside the US embraced the American concept and the unifying label of "Pride," they also redesigned it as their own, adapting it to national, political and cultural contexts (Peterson et al., 2018, p. 64). Over time it became evident that the Pride events are a form of collective action that successfully blends "unity and diversity" (McFarland, 2016: 52-56; Peterson, 2018:22), thus displaying adaptability and context sensitivity that constitute a prominent feature of the ICA framework.

3. ICAs' Diffusion Patterns

In order to examine the hypothesis that ICAs can scale from the micro to the macro level in accordance with recognized patterns of social contagion, we trace the temporal and spatial diffusion patterns of our four case studies.

3.1 Temporal Diffusion

Figure 1 displays the temporal diffusion of food co-ops (first and second waves-1a & 1b), community gardens (1c), MIL events (1d), and Pride parades (globally) (1e).

[8] See, e.g., the conflicts concerning the level of radicalness and the "ban on police" in Friend, 2019.

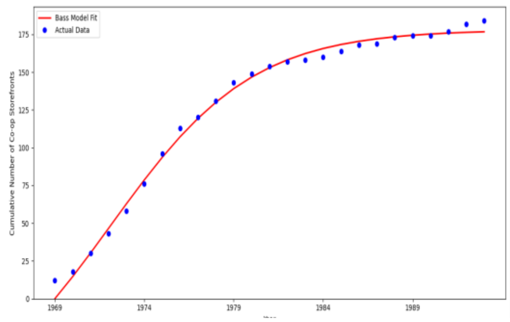

***Fig. 1a*:** Food Co-ops 1967-1993 (First Wave)

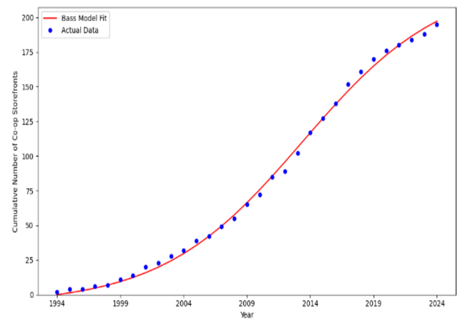

Fig. 1b: Food Co-ops 1994-2024 (Second Wave)

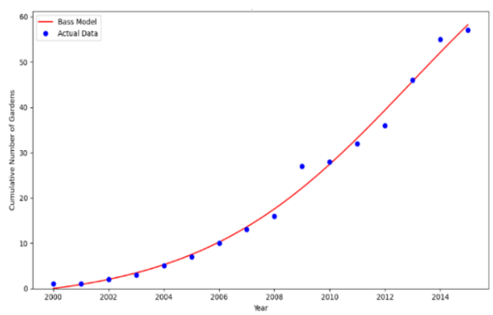

Fig. 1c: Urban Community Gardens 2000-2015

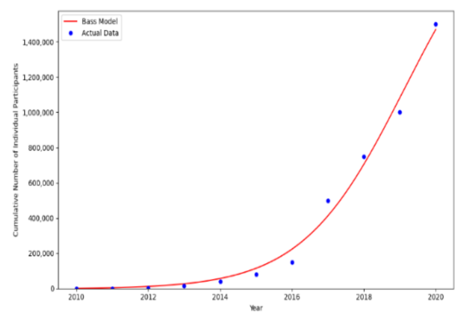

Fig. 1d: Memory in the Living Room 2010-2020

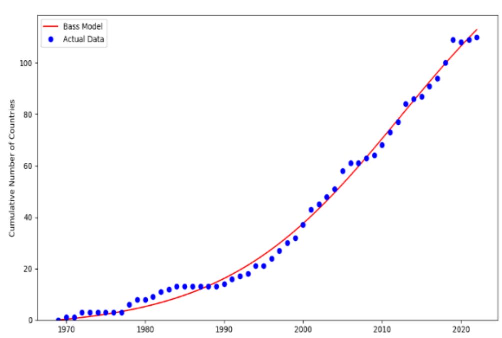

Fig. 1e: Pride Parades (Global) 1970-2022

Figure 1. The X-axis represents the timeline, starting from the first introduction of the relevant ICA. The Y-axis is the cumulative number of adopters (in 1d, this number refers to individuals rather than 'salons'). The actual data (in blue) is displayed against the best fit to the Bass diffusion model (in a consecutive red line).

The temporal diffusion in all four cases follows typical dynamics of complex systems, that were observed in thousands of studies tracing the diffusion of products, technologies, social habits, and more (Rogers, 2003; Bass, 1969; Hopp, 2004). The relatively linear and slow start of the process is followed by a nonlinear increase in the pace of diffusion. This reflects the prevalence of social influence among adopters, the weight of which increases with the increase in the number of adopters. Eventually, the relevant "market" reaches saturation, resulting in a typical diffusion curve that, following saturation, roughly resembles an S-shape (e.g., Rogers, 2003, pp. 349-352; Bass, 1969).[9]

We further test the fitness of the temporal diffusion data to the Bass diffusion model, a fundamental mathematical model that allows to quantify the diffusion process, and evaluate the weight of social contagion (which the model denotes "q") against other independent factors (which the model denotes "p"). [10] Applying the Bass model to our data displays a general fit between the actual diffusion data of the

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[9] As is evident from Figure 1, the diffusion in all our case studies except the first wave of food co-ops has not yet reached saturation.

[10] According to the Bass model, the number $n(t)$ of nodes who adopted an innovation up to time t is given by the following differential equation:

$$\frac{dn(t)}{dt} = \left[p + q\frac{n(t)}{M} \right] \left(M - n(t) \right)$$

where p is the "coefficient of innovation" (which reflects the factors in the decision to adopt the innovation that do *not* result from social influence, such as internal preferences); q is the "coefficient of imitation" (which reflects the social influence in the decision to adopt); and M is the "market potential" (the total number of nodes who will eventually adopt the innovation). The adoption rate dn/dt is given by sum of two components: the first component represents the adoptions by "innovators"-those who adopt the product independently of how many other persons have adopted it before. The second component represents adoptions by "imitators"-those who adopt the product due to interactions with people who have already adopted it. The fraction of imitators is assumed to be proportional to the number of previous adopters. At the beginning of the process $n(t) \approx 0$, and therefore the imitation component, which is proportional to $n(t)$ is very small. This reflects the fact that at the launch of a new innovation, the first adopters are almost entirely "innovators" who adopt due to independent factors. As the process progresses, there are more adopters to be imitated leading to an increase in the rate of diffusion. This rate eventually slows down when the relevant market reaches saturation, and there are fewer remaining potential adopters ($M - n(t) \to 0$) (Bass, 1969). For further discussion of the Bass model and its limitations see, Shur-Ofry et al., 2019.

four ICAs–food co-ops (both waves), community gardens, MIL events, and Pride parades–and the Bass function. Details of the fitness to Bass in each case appear in the Supplementary Materials. This fit provides strong evidence that the diffusion of those four ICAs was indeed influenced by social contagion.

3.2 Clustering

Another evidence for social contagion among ICAs could be the emergence of spatial clusters that are typical of self-organization in complex systems. Clusters are groups of ICAs formed in close spatial proximity to each other. [11] In the case of ICAs such clustering can result from a process of social contagion, whereby an urban community garden, for example, inspires nearby communities to start their own gardens, or an active co-op encourages people in proximal areas to establish additional co-ops. Previous studies of food co-ops indeed observed that the "density" of co-ops in rural areas is a factor that encourages robust co-op development, since the cooperative model "is on the radar" of people (West & Berner, 2021:141-149).

Examining the temporal dimension of clustering can further strengthen the evidence of a diffusion process driven by social contagion. If the emergence of an ICA in a certain geographical area generates social influence and increases the probability of additional ICAs being established in spatial proximity, then we can expect some correlation between the ICAs' formation dates and their spatial locations.

1) Spatiotemporal Clustering

In order to test this hypothesis, we examined the spatiotemporal diffusion of the food co-ops (case study #1), the community gardens (case study #2), and the Pride parades (case study #4). In the latter

[11] Importantly, while our study concentrates on physical clustering, spatial clustering is not limited to physical-geographical spaces. Clusters of nodes that are more connected to each other than to the rest of the network can also emerge in virtual systems such as online social network, case citation networks, or patent citation networks. In such cases, the social contagion that results in cluster formation is not based on geographical proximity but on other forms of interaction.

case we considered both the diffusion of the parades across the United States, as well as globally. We were unable to obtain accurate data on the spatial diffusion of MILs (case study #2). However, since MILs take place in private-intimate spaces, unlike food co-ops, community gardens and Pride events that occupy the public space, their physical observability is lower. We therefore assume that the main conduits of social influence in that case would not be geographical proximity, but rather interactions on social media and human networks.

To visually illustrate the spatiotemporal dynamics, we divided the period since the establishment of the first ICA in each of our case studies to sub periods. We used a gradient color-scale and assigned a different color to each node, reflecting the sub-period of its formation (in the case of co-ops and gardens), or the year in which it first became a 'Pride state'/'Pride country', i.e., when the first parade event took place in the relevant region (in the case of the parades).

If ICAs emerge independently of each other, then one would expect that the different colors would be distributed randomly across the relevant space. By contrast, if the emergence of an ICA (food co-op/garden/Pride parade) in a certain geographical location increases the probability that additional ICAs would be formed in spatial proximity to that location, then we would expect some correlation between the ICAs' formation dates, as expressed by their assigned colors, and their locations in the geographical space. In other words, as opposed to randomly mixed colors, if ICAs exhibit contagion then certain clustering of similar colors in the geographical space is expected.

Figure 2 displays the spatiotemporal diffusion of food co-ops during the first wave (2a), second wave (2b) and both waves combined (2c); the spatiotemporal diffusion of community gardens (2d), and of Pride parades in the United States (2e) and globally (2f).

Fig. 2a Food Co-ops First Wave

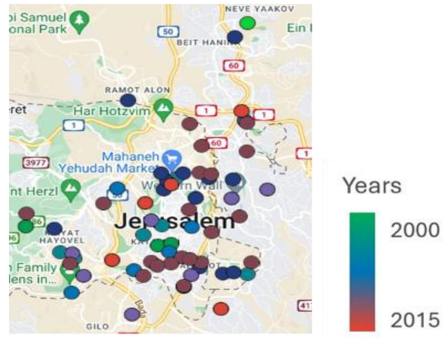

Fig. 2d Community Gardens

Fig. 2b Food Co-ops Second Wave

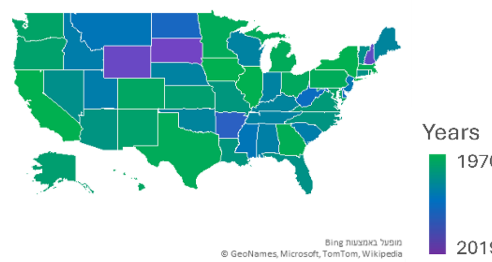

Fig. 2e: Pride parades (US)

Fig. 2c: Food Co-ops-Two Waves Combined

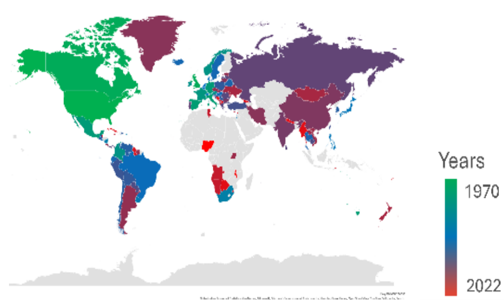

Fig. 2e: Pride parades (global)

Figure 2. 2a-2c depict the spatiotemporal diffusion of food co-ops in the United States during the first wave (a), second wave (b) and combined (c). We divided the period to five-year units and the color of each food co-op reflects the date of its formation, according to the gradient scale on the right side. The grey co-ops in 2b are the co-ops established during the first wave. **2d** depicts the spatiotemporal diffusion of community gardens across

Jerusalem. The color of each garden reflects the date of its formation, according to the gradient scale on the right side. **2e-2f** depict the spatial diffusion of Pride Parades across the United States (e) and globally (f). The color of each state or country (respectively) reflects the date of the first Parade that took place in that state or country, according to the gradient scale on the right side.

Figures 2a-2c indicate that the spatial distribution of same-colored co-ops is not random. Rather, spatial proximities (clustering) can be observed among some of the co-ops that were formed during proximal periods of time. Similarly, figure 2d demonstrates clusters among some of the gardens that were formed during proximal years, while figures 2e and 2f exhibit some degree of geographical clustering among pride Parades too. However, in light of geographical distance, the weight we can ascribe to this spatio-temporal proximity between two "Pride states" or two "Pride countries" as evidence of social contagion is more limited. The clustering of the Pride states and countries, and the source of social influence, may depend more on political and cultural similarities, rather than directly on spatial proximity.

2) Food Co-ops in the North-East region: Correlation analysis

Physical clustering can result not only from social contagion, but also from the natural distribution of populations in geographical spaces (e.g., Batty, 2007). In order to control for this factor and distinguish the spread of ICAs from the underlying spread of the population, we now deepen our analysis and zoom-in to examine the spatial diffusion of food co-ops in the North-East region of the United States. According to previous studies, the North-East region is the area with the highest concentration of food co-ops per population in the United States (Young, 2023; cf. West & Berner, 2021), despite not being densely populated.

Figure 3 compares the co-ops geographical distribution with the underlying distribution of the population that is depicted in gradient colors on the underlying map. The comparison indicates that the distribution of co-ops in the North-East region does *not* overlap with the distribution of the population and thus strengthens the evidence for social contagion.

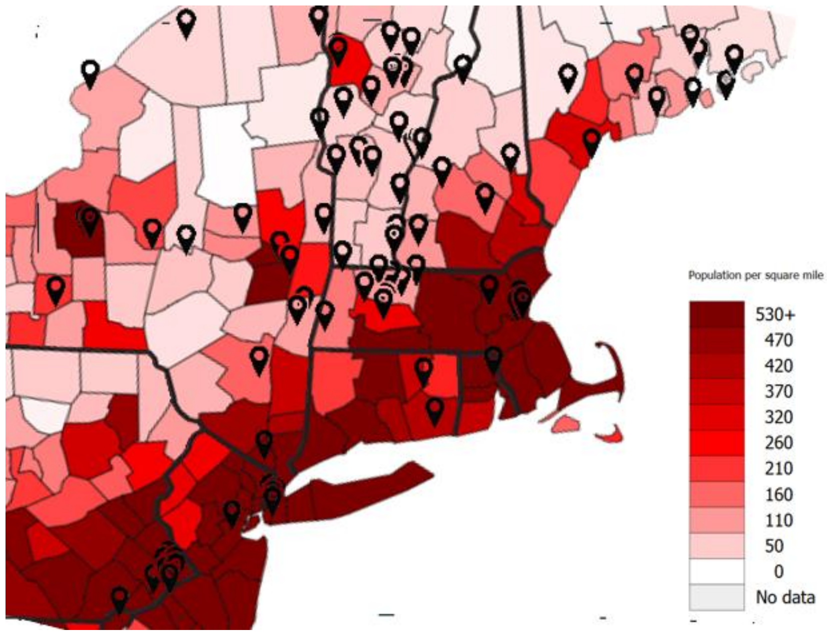

Fig. 3: Spatial distribution of food co-ops in the US North-East region. The figure depicts the co-ops established in the region during the first and second waves, combined (in black), against a map that shows the density of population in the region in gradient colors. Map available at https://ecpmlangues.unistra.fr/civilization/geography/maps/US%20Population%20density,%202010.svg.

We further apply a *correlation analysis*, which allows us to examine whether food co-ops in the North-East region tend to cluster together more than would be expected by random distribution of the co-ops. Such correlation could provide another indication for social contagion among co-ops. We therefore calculate the pair correlation function of the co-ops located in North-East region, in the area marked on the map in Figure 4a.[12] The pair correlation function g(r) measures the probability of finding two co-ops at a distance r from each other, relative to a random distribution. Thus, g(r)=1 indicates a completely random distribution, while g(r)>1 indicates clustering and social contagion.

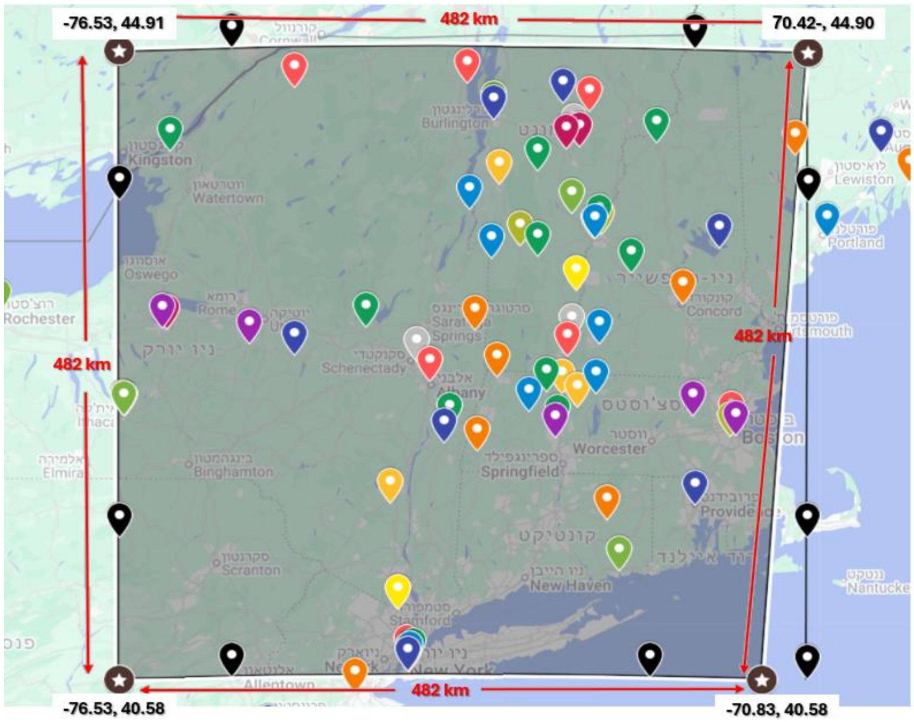

Fig. 4: The shadowed shape shows the area with respect to which correlation analysis was carried out, and the co-ops located therein. In the Google map, the area of the square surface (482km×482km) appears asymmetrical, because latitude lines are roughly parallel, while longitude lines converge at the poles.

[12] For a set of N objects located in two-dimensional space of area A, the pair correlation function is defined as $g(r) = \frac{1}{2\pi r \Delta r \rho} n(r, r + \Delta r)$, where $\rho = \frac{N}{A}$ is the average number density of the objects and $n(r, r + \Delta r)$ is the number of pairs with distance between r and r+Δr.

We compared the 69 actual co-op locations to a randomly generated set of nodes distributed across the same geographic area, converting latitude and longitude coordinates into kilometers to measure real distances and using periodic boundary conditions to avoid edge effects.[13] Figure 5 depicts the correlation function of the co-ops in the region, relative to that of a random set of nodes.

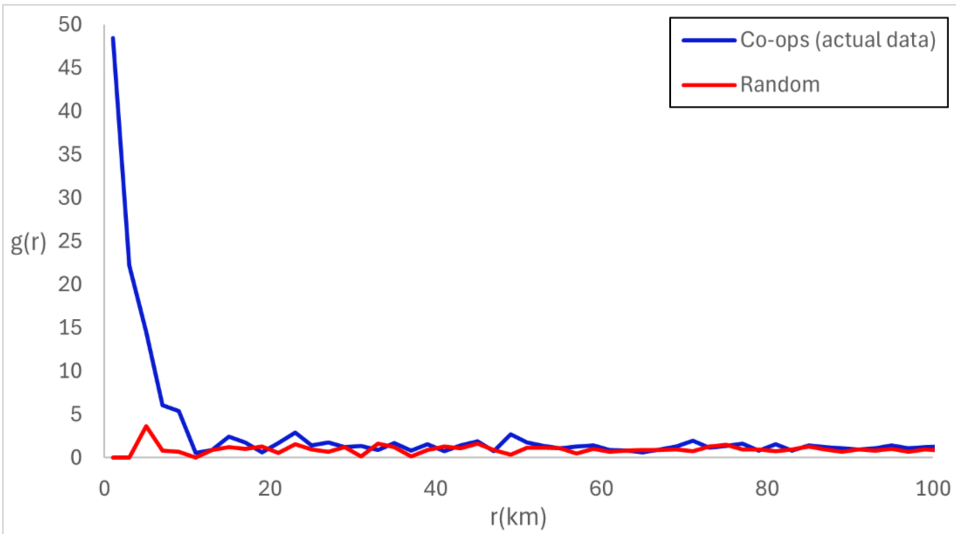

Fig 5: The pair correlation function $g(r) = \frac{1}{2\pi r \Delta r N/A} n(r, r + \Delta r)$ of the co-ops located in the North-East region (blue line) and of a set of points randomly distributed in the same area (red line) for periodic boundary conditions (N=69; A=232,324 km^2; Δr=2 km). The x-axis represents the distance r in kilometers. The y-axis represents the pair correlation function g(r).

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[13] "Edge effects" may distort the calculation since nodes near the edges of the designated area have fewer neighbors than nodes in the interior. To eliminate the edge effects, "periodic boundary conditions" map the plane onto a torus, so that the boundaries of the area are connected to their opposite sides.

The graph in figure 5 shows that the actual co-ops (depicted by the blue line) are significantly more clustered at short distances compared to random points (depicted by the red line): At distances under roughly 10 kilometers g(r)>1, indicating that there are many more co-op pairs close together than expected by chance, and suggesting that new co-ops do indeed tend to form near existing co-ops. As distance increases, the correlation function of the co-ops drops and roughly converges with the random set (g(r)=1). This pattern strongly supports the existence of spatial contagion among co-ops in that region: the presence of a co-op makes it more likely that nearby communities will also establish co-ops, possibly through inspiration, shared knowledge, and local networks—factors that were highlighted in previous studies.

4. Discussion

Our analysis of the temporal diffusion of four different types of ICAs—food co-ops, community gardens, MIL events, and Pride parades—demonstrates a temporal diffusion that fits the Bass model. Such fitness constitutes a strong indication that social contagion played a substantial role in the diffusion process. The diffusion of three of our case studies, the co-ops, the gardens and Pride parades, further exhibits spatiotemporal clustering, which suggests that such contagion may rely, to an extent, on spatial proximity. A focused look at food co-ops in the North-East region of the United States reveals a correlation between the existence of co-ops in a certain geographical space and the formation of additional co-ops in a proximal area, which is another substantial indication for social contagion among co-ops in that region.

Overall, these findings support our hypothesis that ICAs can spread from the micro to the macro scale in accordance with patterns that characterize self-organized diffusion in complex systems. In other words, the scaling of ICAs may occur through a contagion process that can maintain the benefits of the local scale, yet have a macro-level effect. This, in turn, could provide a new solution to the "Scaling Ostrom" problem.

4.1 Scope and Limitations

Let us clarify the scope and limitations of these finding. We do *not* suggest that bottom-up contagion is the *only* way for ICAs to scale.[14] Nor do we argue that ICAs *always* scale from the micro to the macro level in accordance with these diffusion patterns. Similar to how products and technologies not always follow the typical diffusion dynamics, some ICAs may deviate from these patterns or fail to diffuse entirely. Nevertheless, given the prevalence of self-organized diffusion patterns among products, technologies, and social practices, we expect that the diffusion of many ICAs, too, will follow these dynamics.

Interestingly, unlike simple diffusion of products and technologies within a social system, the scaling of ICAs seems to involve natural adaptation to local contexts. The case studies of food co-ops, community gardens, MILs and Pride parades suggest that the interactions among the individual ICAs are not simple acts of 'imitation', but rather a more complicated, dialectic process, that generates adaptation to the needs and preferences of local communities. These interactions can give rise to collective phenomena that are not simple aggregations of identical micro-components: a movement toward a more active, socially oriented system of food consumption in the case of food co-ops; a shift in the urban landscape in the case of community gardens; changes in the collective memory of the Holocaust in the case of MILs, or in a collective LGBTQ+ culture fostered by Pride parades. This observation aligns with Ostrom's insights regarding the inherent adaptability of ICAs to local populations. It also resonates with the notion of 'More is Different'—articulated by Nobel laureate Phil Anderson, one of the founding fathers of complexity—which is

[14] For scholarship exploring other modes of "commons scaling", see, e.g., Rennie & Potts, 2024; Potts, Torrance, Harhoff & von Hippel ,2023.

considered today as one of the organizing principles of complex-systems science (Anderson, 1972; Shur-Ofry, forthcoming, pp. 31-32).

4.2 Law and Policy Implications

These findings have significant policy implications. *First,* they suggest that because ICAs may naturally scale from the micro to the macro level they can play a more significant role in addressing collective action challenges than has been previously recognized. As the history of Pride suggests, a local ICA such as the Stonewall protests in Greenwich Village can evolve into a collective cultural and political phenomenon, spread to most of the world's countries, and generate a global change. Likewise, in the case of MIL, a local gathering in a private living-room can scale to the macro, state, level, and influence the collective memory of an entire community.

Second, while the dynamics governing the spread of ICAs are grassroot in nature, they *follow typical patterns*. Policymakers familiar with these patterns can influence the diffusion of ICAs, without resorting to heavy, expensive, top-down interventions. For instance, municipalities aiming to promote 'green cities' could support spontaneous, locally organized communities by providing 'tail wind' to bolster an emerging diffusion process. This could involve actively initiating a few community gardens in different geographical areas of the city to trigger the self-organized formation of additional gardens in nearby locations, ultimately creating an overall impact on the urban environment (Lehavi 2009; Malcai & Shur Ofry, 2019). Similarly, a state seeking to encourage cooperative farming among communities could sow seeds by launching a few state-supported initiatives across a region, which may, over time, trigger similar collaborations within additional communities.[15] Policymakers could also closely track the spontaneous spatial diffusion of ICAs, and focus their support on weaker areas of the

[15] This example is inspired by extant cooperative farming initiatives in Africa. See, e.g., Solidaridad Network, 2024.

region—typically, the peripheral zones, where spontaneous diffusion may be slower to reach.

Third, and relatedly, our findings add to the vast literature on the use nudges to solve challenges of collective action.[16] Literature has already observed that nudges can facilitate and promote ICAs (Foster, 2011: 96). Our study, however, suggests that nudges may be self-expanding. In other words, delicate interventions might trigger a self-amplifying process that will eventually result in a significant, macro-level social effect. Such *self-expanding nudges* would typically be cheap to implement, since the required investment is at the micro-level, while the eventual outcomes are at the macro-level.

Fourth, a cautionary note: The dynamics of self-organization we identify here should not be idealized, and are not expected to result in equal distribution of ICAs. Self-organization is not an egalitarian movement. Rather, complex systems operate through preferential attachment mechanisms that ordinarily generate unequal distribution of resources. Therefore, complexity-informed policymakers can anticipate that, absent intervention, the spontaneous diffusion of ICAs will produce uneven distribution. For example, the first Jerusalem community gardens emerged in the city center and took longer to reach the city's periphery. Their diffusion across the urban landscape followed a fractal shape and a core-to-periphery trajectory, with higher densities in central areas and lower densities in peripheral neighborhoods (which are typically also the weaker neighborhoods).

Therefore, when equality is a desideratum, policymakers can actively monitor for emerging inequities in diffusion processes and calibrate their interventions accordingly. For example, carefully tracing clusters of ICAs that are beginning to emerge spontaneously across a space allows local authorities to identify the 'voids', namely the empty

[16] Nudges are measures that can "alter people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler & Sunstein, 2008: p. 6).

areas we expect to find in-between clusters, and to actively support those weaker areas, typically the peripheral zones, where spontaneous diffusion may be slower to reach.

Finally, the understanding of the dynamics according to which nudges can self-expand and commons-governance can scale, may have broader implications beyond those discussed here. While our case studies focus on salutary ICAs that generate positive effects, ICAs could also generate disputable and even harmful outcomes—crime cartels being an obvious example. There is reason to assume that such 'negative ICAs' would also spread through social contagion and spatial proximity (e.g. Weisburd et, al, 2012; Papachristos et al., 2013), in accordance with the patterns we describe here, which in turn can have important implications for the regulatory effort to curb them. Secondly, our analysis could also have implications for ICAs that lack a physical spatial dimension, namely for the governance of virtual knowledge resources (Frischmann, Madison & Strandburg, 2010; Frischmann, Madison & Strandburg, 2014; Frischmann, Madison & Strandburg, 2018). We mark these as topics for future research.

5. Conclusion

Complexity theory and the methods used to investigate typical growth patterns of complex systems shed new light on the significance of informal collaborations as a potentially efficient mode of overcoming collective action problems. Applying this lens enables us to identify a new potential solution to the challenge of scaling ICAs, often raised against the Ostrom approach, cautions against over-idealization of this solution, and supplies a set of tools for policymakers wishing to harness this understanding for crafting targeted and effective policy interventions. The case studies and legal-policy implications we discuss here are, of course, not exhaustive. Translating this study's insights into concrete policy recommendations requires close scrutiny and data gathering in additional specific settings. Hopefully more studies in this vein will follow.

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