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The spatial structure of transnational human activity

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ABSTRACT

Starting from conflictive predictions of hitherto disconnected debates in the natural and social sciences, this article examines the spatial structure of transnational human activity (THA) worldwide (a) across eight types of mobility and communication and (b) in its development over time. It is shown that the spatial structure of THA is similar to that of animal displacements and local-scale human motion in that it can be approximated by Lévy flights with heavy tails that obey power laws. Scaling exponent and power-law fit differ by type of THA, being highest in refuge-seeking and tourism and lowest in student exchange. Variance in the availability of resources and opportunities for satisfying associated needs appears to explain these differences. Over time (1960–2010), the Lévy-flight pattern remains intact and remarkably stable, contradicting the popular notion that socio-technological trends lead to a "death of distance." Humans have not become more "global" over time, they rather became more *mobile* in general, i.e. they move and communicate more at all distances. Hence, it would be more adequate to speak of "mobilization" than of "globalization." Longitudinal change occurs only in some types of THA and predominantly at short distances, indicating regional rather than global shifts.

1. Introduction

A hungry shark searching for prey in the ocean will frequently move short distances, interrupted by random changes of direction that are only occasionally followed by moves over longer distances. Sorting the displacement lengths covered in this journey by size and frequency results in a distribution with a long tail that obeys a power law.[1] Such mobility patterns, so-called Lévy flights,[2] have been shown to occur not only in the foraging movements of sharks and other marine predators like sea turtles and penguins (Sims et al., 2008), but also in the motion of smaller species like plankton (Bartumeus et al., 2003). For humans, Lévy-like patterns have been found in local (Gonzalez et al., 2008; Song et al., 2010; Rhee et al., 2011) and nation-wide mobility (Brockmann et al., 2006). Whether *planet-scale* human activity also follows a Lévy flight has however not been thoroughly examined to date. Thus, the global sphere has largely been omitted by this natural-scientific strand of research. Conversely, the *social*-scientific literature that deals with the global sphere has not yet taken the

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[1] A power law describes the relationship between two quantities, where one quantity varies at the power of the other. Mathematically, the power-law relation between two quantities y and x can be defined as $y = ax^{-\beta}$, where a is a prefactor and β is the scaling exponent. Power laws are common in the social and natural world and have been shown to exist in phenomena as diverse as the gamma-ray intensity of solar flares (Clauset et al., 2009), the sizes of strike waves (Biggs, 2005), or the distribution of accusations between prisoners (Deutschmann, 2016).

[2] A Lévy flight is a random walk (i.e. a succession of steps into random directions) in which the step-lengths feature a heavy-tailed probability distribution. For a precise mathematical definition, cf. Shlesinger and Klafter (1986). In empirical research, Lévy flights are usually diagnosed by "showing that the power-law distribution holds" (Buchanan, 2008, p. 715).

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findings of the Lévy-flight debate into account. On the contrary, it is dominated by the idea that technological and socio-economic trends have led to a diminishing or even vanishing role of physical distance in structuring human activity. Symptomatic are shibboleths like "demise of geography" (Toffler, 1970), "time-space compression" (Harvey, 1989), "end of geography" (O'Brien, 1992), "collapse of space" (Kirsch, 1995), "death of distance" (Cairncross, 1997), and "flat world" (Friedman, 2007).[3]

The natural- and social-scientific positions on this matter thus lead to entirely irreconcilable predictions: a heavily bended power-law curve in the former case against a flat line in the latter. The lack of attempts to resolve this glaring discrepancy (or at least to run a rigorous planet-scale analysis) is astonishing given the importance of the topic. Cross-border mobility and communication has not only grown exponentially over the last decades (cf. section 5.2), but is has also led to significant societal and environmental change and spurred fervid public debates around the world, for instance concerning the current high number of transnational refugees and asylum-seekers (Lee, 2015). Moreover, many problems humanity is facing today, from warfare and health epidemics like H5N1 and Ebola to climate change and global wealth disparities are heavily intertwined with transnational human mobility and communication. Driven by the hope that a better understanding of how people move around the world can contribute to solving such pressing social problems, a group of researchers has recently challenged the scientific community to get active and "to collect large-scale human mobility traces" (Hui et al., 2010). The aim of this article is to respond to this call and to fill in some missing pieces, namely to add the global-scale analysis to the natural-scientific Lévy-flight debate, and the Lévy-flight analysis to the social-scientific globalization debate. In specific, we search for answers to the following research questions:

1. Does the spatial structure of transnational human activity follow a Lévy flight?
2. Does the spatial structure differ by type of activity, and if yes – why?
3. Has the spatial structure of transnational human activity changed over time?

To do so, data on five types of mobility (asylum-seeking, migration, refuge-seeking, student mobility, tourism) and three types of communication (phone calls, online friendships, remittances) from a range of sources was standardized to cover the same set of 196 sending and receiving countries (i.e. 38,220 country dyads). In total, the structure of about 2 million valued ties across 53 network matrices at various time points between 1960 and 2010 were analyzed, involving, inter alia, 6.7 billion tourist trips and 240 billion international phone call minutes. While the online friendship dataset is entirely new and thus original in itself, the major innovations of this study consist in (a) linking hitherto disconnected natural- and social-scientific debates by (b) offering a new explanatory model that combines elements of these debates to predict spatial patterns *ex ante*, and (c) conducting the first encompassing comparative analysis of the spatial structure of transnational human activity worldwide, over time, and across various types of mobility and communication.

Our findings cast doubt on the accuracy of prevailing ideas in both the natural- and the social-scientific research strands in question: random food search optimization as the hegemonic theoretical argument in the Lévy-flight debate and the popular notion in globalization studies that socio-technological trends lead to a "shrinking" world in which physical distance is rendered irrelevant. Our analysis shows that the mobility patterns of transnationally active humans (who take conscious, information-based decisions) are very similar to those of other species at lower scales and that humans have *not* become more "global" over time; they rather became more *mobile* in general, i.e. they move and communicate more *at all distances*. Accordingly, it would be more appropriate to speak of "mobilization" than of "globalization." Longitudinal change occurs only in some activity types and predominantly at short distances, indicating regional rather than global shifts.

This article is organized as follows: first, we review the existing literature and theories concerning the spatial structure of human and non-human activity (section 2). We then set out our own conceptual approach (3). Next, the data and methods are described (4). Finally, we present the results (5), focusing first on the current spatial structure (5.1), then move to examining longitudinal trends (5.2), and finally compare our results to theoretical scenarios and results from other studies (5.3). We conclude with a summary of our findings and a discussion of their implications (6).

2. Theory and state of research

The literature on the spatial structure of human activity can be described as consisting of three separate streams: (a) the Lévy-flight debate, (b) the geography-is-dead debate, and (c) the distance-decay debate. In the following, we briefly review these streams of research, highlighting their achievements and deficits.

2.1. The Lévy-flight debate

The Lévy-flight debate is carried out mainly by natural and complexity scientists and began with research that showed that the motion patterns of many non-human species, from mammals like spider monkeys (Ramos-Fernández et al., 2004) to marine predators like sharks, sea turtles and penguins (Sims et al., 2008) and much smaller organisms like plankton

[3] As we will see (section 2.3), a third stream of research has argued that such statements are exaggerated and that geographic space (still) structures social relations. Yet, a rigorous empirical analysis of the association between distance and planet-scale human activity is also missing in that strand.

(Bartumeus et al., 2003), follow power laws. While some of the early alleged Lévy-flight diagnoses (e.g. for albatrosses) turned out not to hold upon closer scrutiny (Buchanan, 2008), the debate remains vital and was recently expanded to human mobility. Lévy-like mobility patterns have now been found in studies that followed the GPS traces of volunteers on university campuses, theme parks, state fairs, and in cities (Rhee et al., 2011; Noulas et al., 2012), the movements of mobile phones (Gonzalez et al., 2008; Song et al., 2010), and the traces of banknotes in the United States (Brockmann et al., 2006).

The theoretical argument for the Lévy-flight pattern is – at least for animal motion – the optimization of food search. It has been shown that in environments where food is randomly dispersed and scarce, a power-law distribution of flight lengths with a scaling exponent $\beta = 2$ is the optimal search strategy (Viswanathan et al., 1999). For human mobility, though, the existing papers contain little theoretical reflection as to *why* the Lévy flight should apply (e.g. whether the goals humans pursue in their everyday life are readily equitable with foraging). Another critical point is that in contrast to the random walk that underlies the Lévy-flight model, humans do not actually move into *random* directions. It is more likely that the directions are determined by needs humans seek to fulfill (Noulas et al., 2012) or the information they have about their environment (Hägerstrand, 1967; Miller, 1972). Yet, while this discrepancy has repeatedly been recognized (Rhee et al., 2011; Song et al., 2010), little has been done to overcome it. The biggest shortcoming of the Lévy-flight debate however are its current scale and data restrictions: US-dollar bills for instance can only be used in the United States and "it remains unclear whether the observed properties are specific to the US or whether they represent universal features" (Brockmann and Theis, 2008, p. 33). Two recent studies (Cheng et al., 2011; Noulas et al., 2012) have shown that log-ins to location sharing services (LSS) like Foursquare follow a Lévy-flight pattern on a global scale. Yet, LSS require smartphone access and are used only by a small, well-off minority of the world population. Mainstream forms of planet-scale mobility and communication (including poverty-driven ones) are disregarded by the Lévy-flight debate as yet, as is potential longitudinal change.

Despite these limitations, the Lévy-flight debate is highly pertinent to the issue of how planet-scale human activity is structured. After all, humans are animals, too, and the question is whether we move and communicate just like other species, or whether our distinct capacity to process information and our advanced ability to develop technological means for overcoming physical distance lead to different spatial patterns.

2.2. The geography-is-dead debate

The idea of a decline and eventual vanishing of the role of space in structuring human interaction has a long history and takes many facets. Already in the mid-19th century, Marx and Engels argue that "[i]n place of the old local and national seclusion and self-sufficiency, we have intercourse in every direction, universal interdependence of nations" (1948[1848], p. 12). Later, Marx coins the term "annihilation of space by time" to describe the tendency of capital (and in its wake all parts of society) to "tear down every spatial barrier to intercourse" (1973[1939], p. 539). In 1962, McLuhan claims that the "new electronic interdependence recreates the world in the image of a global village" (1962, p. 31). A decade later, Toffler coins the term "demise of geography" alleging that in contrast to the nomads of the past who were bound by place, "the new nomads of today leave the physical structure behind" (1970, p. 91). Similarly, O'Brien purports the "end of geography" (1992) in financial markets, while Cairncross maintains that "[t]he death of distance as a determinant of the cost of communicating will probably be the single most important force shaping society in the first half of the next century" (1997, p. 1). Luhmann (1997, p. 809), no less dramatic, concludes that instantaneous worldwide telecommunication depletes spatial borders, leading to a world system in which all operations and events occur simultaneously, or, in other words, a fully actualized world society. Ten years further down the road, Friedman states that we entered a new era of globalization which "is shrinking the world from a size small to a size tiny and flattening the playing field" (2007, p. 10). The central characteristic of this new era, he argues, is "the newfound power for individuals to collaborate and compete globally" (Ibid). Numerous other terms, such as "time-space compression" (Harvey, 1989), "collapse of space" (Kirsch, 1995), "shrinking world" (Allen and Hamnett, 1995), "deterritorialization" (Appadurai, 1996), "collapse of time and distance" (Koehn and Rosenau, 2002, p. 105), and "increasing emancipation from space" (Schroer, 2006) have been proposed to describe the very matter.

The recurrent argument in this debate is that technological innovations, declining costs, and massive growth of transport and communication infrastructure lead to a world in which physical distance plays a smaller or even no role at all anymore, first and foremost for flows of money and messages, but also for the movement of commodities and individuals. The geography-is-dead debate in its current and past forms has largely been driven by theoretical arguments with little empirical grounding. Yet its arguments have been highly influential in the social sciences and popular in the public sphere. It is completely detached from the Lévy-flight debate (and *vice versa*), but another stream of more empirics-oriented research, the distance-decay debate, has – explicitly and implicitly – referred to it critically.

2.3. The distance-decay debate

This third stream of research acknowledges the (continuing) salience of distance in structuring human activity, however usually without analyzing the precise shape of this relation. Most studies do not go beyond the notion that physical proximity (still) matters. A typical statement, which became known as Tobler's First Law of Geography, is: "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236). Other central terms are the "principle of least effort" (Zipf, 1949) and "distance decay". "Distance decay" is used in a wide range of fields from criminology, where it is known that offenders tend to commit crimes in proximity to their residency (Rengert et al., 1999), to eco-

geography, where studies found that biological similarity decreases with geographical distance (Soininen et al., 2007). In military science, the continued importance of the "loss of strength gradient" has been emphasized (Webb, 2007). Several studies on international trade and transport costs have explicitly criticized the idea of a "death of distance" as exaggerated (Kano et al., 2013), unfounded (Leamer and Levinsohn, 1995), or even maintained the opposite: that instead of diminishing or disappearing, the effect of distance on trade rather *increased* during the 20th century (Disdier and Head, 2008).[4]

With respect to human mobility, Ravenstein (1885) studied the "laws of migration" using census data from 19th century England. Although his contemporaries thought that the term "laws" was inappropriate (Ibd, p. 233), he realized that the large majority of migrants only moved short distances while few migrants moved long distances. Later, Stouffer (1940) presented graphically a spatial distribution of family movements in Cleveland that featured a heavy tail. In the early 1950s, Hägerstrand (1967) examined the spatial structure of migration and phone calls in two Swedish districts. He found power-law relations (although he does not use the term) and concluded that "[t]he average telephone-call field or migration field displays a diminishing intensity of contacts with increasing distance from its origin" (Ibd., p. 234).

Concerning *transnational* human activity, the central structuring role of geographical distance has been recognized in a number of empirical studies. For transactions like diplomatic exchange and mail flows, geographic proximity was described as "the most compelling force of attraction in the international system" (Brams, 1966, p. 889), "a very pronounced influence and constraint on the pattern of West European communications and interactions" (Clark and Merritt, 1987, p. 226) and "one of the major factors in global communication networks" (Choi, 1995, p. 181). McKercher et al. (2008) used the concept of "distance decay" in relation to international tourism. Focusing on 41 countries, they showed that 80 percent of all international travel occurs to countries within 1,000 km distance. Pertaining to the supposedly placeless digital world, a recent study on the spatial structure of the internet found an effect of physical distance in the form of a power law with a cutoff (Tranos and Nijkamp, 2013), while another study only reported that the structure of transnational Facebook friendships was "apparently influenced by geography" (Ugander et al., 2011, p. 13). Takhteyev et al. (2012, p. 78) showed a distribution of Twitter messages by geographical distance in which distance clearly mattered, however without analyzing this relation further.

Two explanations have been put forward as to why human mobility is affected by geographic space (cf. Miller, 1972; Noulas et al., 2012). The first one, the *gravity* hypothesis, is inspired by Newton's law of gravity and states that costs connected to distance itself are responsible for fewer long distance movements (Deutsch and Isard, 1961, p. 308; Zhou, 2011, p. 197). The second one, the *intervening opportunities* hypothesis, argues that it is not the costs of distance itself that matter, but intervening opportunities that allow one to fulfill one's needs already at close distances, making long-distance mobility unnecessary (Stouffer, 1940; Freymeyer and Ritchey, 1985).

While more empirics-oriented than the geography-is-dead debate, an encompassing analysis of the precise shape of the relation between distance and various types of human activity at the global scale is also missing in this stream of research. Moreover, to our knowledge no study has tracked change in the spatial structure of human mobility or communication over time.

3. Conceptual approach

Our aim is to analyze and compare the spatial structure of various types of *transnational human activity* (THA). We use THA as an umbrella term for transnational human *mobility* (THM), which denotes activities in which individuals cross nation-state borders physically, and transnational human *communication* (THC), which comprises communicative acts across nation-state borders that do not directly involve physical mobility. Note that both definitions only imply that national borders are *crossed*, not that they *dissolve*. A dissolution of national borders may of course occur – the field of transnational migration studies has rightly broached this issue (Basch et al., 2005; Khagram and Levitt, 2008) – but for the purposes of this study it suffices to assume that individuals and information flow *between* countries. Yet, we do not use the term "*inter*national" (*inter* = "between" in Latin), because it is used in International Relations to describe affairs between governments. "Transnational" by contrast is conventionally used to denote "movements of tangible or intangible items across state boundaries when at least one actor is not an agent of a government or international organization" (Nye and Keohane, 1971, p. 25). This is also in line with how "transnational" is applied in contemporary sociological research on cross-border activities (e.g., Gerhards and Rössel, 1999; Mau, 2010; Kuhn, 2011; Delhey et al., 2015). We add the intermediary term "human" to distinguish our subject of analysis both from non-human animals (as analyzed in the natural-scientific Lévy-flight debate) and from inorganic actors such as multinational companies and non-governmental organizations. One peculiarity of the term "transnational" is its lack of a "closing dimension" (Delhey et al., 2014): while it is clear where transnational activity begins – i.e. when a national border is crossed – it remains unspecified *how far it goes* or *where it ends*. Hence, "[i]t is an empirical question whether […] transnational transactions are global or regional" (Faist, 2010, p. 1637). By analyzing the spatial structure of transnational human activity, we will thus also shed new light on the missing closing dimension of transnationalism.

[4] In contrast to the Lévy-flight debate's assumption of a non-linear power-law relation, these economic studies seem to assume a linear relation (e.g. when describing the influence of distance on trade in the form of a single "distance coefficient" or "elasticity"), as such mean effect sizes would otherwise be rather meaningless.

Building on the Lévy-flight debate, we first test to which extent various types of THA feature a probability distribution whose tail follows a power-law function of the form

$$P(r) \propto r^{-\beta}$$

where $P(r)$ is the probability of a displacement length r to occur and β is the scaling exponent. A larger β means that the curve is steeper, i.e. relatively more activity occurs at short distances, whereas a smaller β denotes a flatter relation, i.e. relatively more activity takes place over longer distances. We expect β and the fit of this power-law function (measured by R^2) to vary by type of THA. For THM, the logic of our argument, which is inspired by the distance-decay debate (and in specific the intervening-opportunities hypothesis), is the following: if we accept the assumptions that

(i) THM is associated with type-specific goals,
(ii) the availability of opportunities for goal-attainment varies by goal,
(iii) the average amount of resources available to attain goals varies by type of THM,
(iv) humans aim at spending as little of their resources as necessary to attain their goals,

then the spatial structure of a specific type of THM i can be expected to be determined by two factors: the availability of opportunities for attainment of the goals associated with i and the resources available on average to the individuals engaging in i. The broader the availability of opportunities for goal-attainment, the higher is the likelihood for individuals to stop their movement at closer locations (and thus the higher R^2 and β), because their needs are already fulfilled to a satisfying extent and any further movement would only diminish the stack of resources without leading to additional benefits. Similarly, the higher the average amount of resources available to the group of people engaging in a particular type of THM, the less they will be physically bound by the costs of THM (and thus the lower R^2 and β), ceteris paribus. The real world is of course more complex, but this simple model may already help to obtain a first explanation for systematic differences between spatial structures of various mobility types.

Our considerations allow to delineate specific expectations for the five types of THM under study (Table 1). Major goals commonly associated with refuge- and asylum-seeking are mere survival, fulfillment of basic needs and security. These goals can usually be fulfilled in many places, oftentimes already in neighboring countries just outside a warzone, locality of oppression or natural disaster scene. The resource stock available to refugees and asylum-seekers tends to be rather low. As a result, the spatial structure of refuge- and asylum-seeking is expected to feature a high power-law fit and scaling exponent. Tourists are often interested in a pleasant, entertaining environment (if on holidays) or in business opportunities (if on business trips). Both are widely available in many countries around the world (and easier to pursue in closer ones, e.g. due to cultural similarity), but tourists are likely to possess more resources on average than refugees. Therefore, R^2 and β should still be high for tourism but slightly lower than for refuge-seeking. Migrants are often interested in improving their economic well-being, which is quite stratified globally and although moving short distances may already result in relative improvements, moving a bit further may in many cases still lead to additional benefits.[5] Migrants are also likely to possess more resources on average than refugees, so that overall we expect a medium R^2 and β. International students tend to aim for excellent education and social distinction, which is best available only in a small number of institutions in a select number of countries, as the global university system is highly stratified (Barnett and Wu, 1995). In theoretical terms, this stratification leads to a lack of intervening opportunities: students cannot just go to neighboring states but have to reach countries like the

Table 1
Theoretical expectations concerning THM.

	Major goal(s)	Ubiquity	Resources	Power-law fit (R^2)	Scaling exponent (β)
Refugees and asylum-seekers	Survival, fulfillment of basic needs, security	High	Low	High	Large
Tourists	Entertainment, pleasant environment/business opportunities	High	Medium	Medium-high	Medium-high
Migrants	Economic well-being	Medium	Medium	Medium	Medium
Students	Education, distinction	Low	High	Low	Small

[5] Migrants are a particularly large group of people with diverse sets of attributes. Some of them are high-skilled experts, which some countries actively seek to attract, while others are low-skilled, untrained workers, who often have to cross borders illegally. The migration data used in this study does not allow to differentiate between such skill types, but in theory this is of course possible. The larger resource stock of high-skilled migrants (in terms of financial, human, and social capital), as well as the more disperse opportunity structure for getting highly-paid knowledge-based jobs compared to the broad availability of low-paid untrained work suggests that they are less bound by gravity (which should result in lower R^2 and β values) than low-skilled migrants.

United Kingdom or the United States to attain their goals. Therefore – and because international students will also be comparatively well-situated on average – we expect low R^2-and β-values for student exchange.

For THC, our argument is inspired by the geography-is-dead debate. First of all, the spatial structure of THC will to some extent be a function of THM, as people will often communicate with friends, kin, or business partners that have gone abroad. Yet, over and above, there may be variance inherent to the specific type of THC that depends on its technological standard and usage cost structure. This argument can easily be explained by comparing phone calls with online friendships. The two networks are similar in that both should to a certain extent resemble THM. Yet, they are different in that the monetary costs of international telephone communication are relatively high and increase with distance (Cairncross, 1997, p. 6), while the material costs of online friendships are low and independent of distance: for someone from Switzerland, having an online friendship with an Austrian is as cheap as having one with an Australian, but calling Australia by phone is far more expensive than calling Austria. Accordingly, we expect the spatial structure of online friendships to be "flatter" and more detached from the power-law pattern (reflected in lower β and R^2 values) than the spatial structure of phone calls. Remittances are special in that they are additionally influenced by economic power and we refrain from formulating a specific hypothesis about its spatial structure *ex ante*.

In the longitudinal part of the analysis, we build on the geography-is-dead debate's arguments in expecting the world to become "flatter" with globalization, and thus the type-specific R^2-and β-values to decline over time. In a final analytical step, we contrast the empirical THA distribution with three ideal geography-is-dead scenarios.

In sum, our conceptual approach uses elements from all three existing research strands, but in combining them goes beyond what they can achieve individually: the geography-is-dead literature contains a useful hypothesis concerning over-time change but lacks the technical means to seriously test them. These means become available by introducing the Lévy-flight debate's power-law approach, which in turn has little to say about over-time developments and lacks theory concerning factors that structure *human* activity. Such factors can to some extent be delineated from the distance-decay literature, in specific the gravity and intervening-opportunities hypotheses. Hence all three strands are relevant; yet the outcome is much more than the sum of its parts. The major innovation of our conceptualization is the possibility for comparison, both across specific types of mobility and communication as well as across time, and the facility to delineate hypotheses about the outcome of such comparisons *ex ante*.

4. Research design

4.1. Data

The empirical part of this study is based on directed network matrices for eight types of THA at various time points between 1960 and 2010 as well as an undirected matrix for geographic distance, all of which were standardized to cover the same set of 196 sending and receiving countries (full list available upon request).[6] Each of the 53 THA matrices thus contains information on $196 \times 196 - 196 = 38{,}220$ country dyads. For the measurement of *geographic distance* we draw on CEPII's *GeoDist* dataset (Mayer and Zignago, 2011). We use the weighted geodesic distance (*distwces*), which provides the average distance between countries based on the spatial distribution of the population in the countries' 25 largest cities. In addition, we utilize *population* data gathered by the United Nations (2013).

Table 2 provides a summary of the eight types of THA under study. Of the eight activity types, five involve physical mobility (THM): asylum-seeking, migration, refuge-seeking, student exchange, and tourism. Data on *asylum-* and *refuge-seeking* was obtained from UNHCR. According to the 1951 Refugee Convention (as broadened by a 1967 Protocol), a refugee is defined as a person who:

> "owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country; or who, not having a nationality and being outside the country of his former habitual residence as a result of such events, is unable or, owing to such fear, is unwilling to return to it." (UNHCR, 2014a)

An asylum-seeker in turn is "someone who says he or she is a refugee, but whose claim has not yet been definitively evaluated" (UNHCR, 2014b). Data on *migration* was extracted from the World Bank's Global Bilateral Migration Dataset for

[6] The set of 196 countries in the standardized matrices was obtained by excluding countries that were not contained in the original datasets of all types of THM under study. For some types of THC, the original set of countries was smaller and the matrices were artificially expanded. We decided to follow this inclusive approach as a more exclusive one would have resulted in a small, limited remainder of countries that would hardly allow speaking of a planet-scale analysis anymore. We set missing values to zero in all matrices, thereby following the example of Reyes (2013, p. 154), who showed the robustness of this approach for the UNWTO tourism dataset and finds that alternative procedures like multiple imputation lead to similar outcomes. In order to make the student and phone-call matrices from earlier years comparable with recent ones, historic states were replaced with their currently existing "equivalents". For example, Dahomey was equated with Benin, Upper Volta with Burkina Faso, and so on (full list of equations available upon request). This procedure does obviously not do justice to the complexity of historic developments, but what matters for the purposes of this article is a similar geographic location, not precise historic equivalence. The World Bank migration data, which also goes back to 1960, already comes in the form of currently existing states for all years in its original format.

Table 2
Types of THA used.

	THA type	Weight in THM/THC indices (%)	Weight in THA index (%)	Available years	Data source(s)
THM	Asylum-seekers	00.1	60	2010	UNHCR (2013)
	Migrants	16.9		1960–2010	World Bank, UN (2012)
	Refugees	00.8		2000–2010	UNHCR (2013)
	Students	00.2		1960–2010	INA (2013), UNESCO (2013)
	Tourists	82.0		1995–2010	UNWTO (2014)
THC	Online friendships	33.3	40	No date	Facebook (2012)
	Phone calls	33.3		1983–1995	INA (2013), ITU
	Remittances	33.3		2010	World Bank (Ratha and Shaw 2007)

the years 1960–2000 (Özden et al., 2011), supplemented by United Nations data for the year 2010 (UN, 2012). The latter source defines migrants as "foreign-born" persons, or, where data on place of birth is unavailable, as "foreign citizens" (UN, 2012, p. 3). Information on transnational *student mobility* was obtained from Princeton's International Networks Archive (INA, 2013) for the years 1960–1998 and from UNESCO for the years 2000–2010. UNESCO defines international students as "[s]tudents who have crossed a national or territorial border for the purposes of education and are now enrolled outside their country of origin" (2010, p. 264). Data on *tourism*, available from 1995 to 2010, was obtained from the World Tourism Organization (UNWTO), according to which "[a] visitor (domestic, inbound or outbound) is classified as a tourist (or overnight visitor) if his/her trip includes an overnight stay" (UNWTO, 2008). Here, we are interested in "arrivals of non-resident tourists at national borders, by country of residence".[7] Note that this definition does not premise any specific visiting purpose and may thus include business travel just as holiday trips.

Three types of THA under study represent indirect communication (THC): online friendships, phone calls, and remittances. *Online friendships* are based on Facebook data which was retrieved from an interactive graph that is available online (Facebook, 2012) and converted into a network matrix. For each country *c*, this matrix contains the five countries to which *c*'s population is most connected via Facebook friendships, ranked from 5 (highest number of Facebook friendships) to 1 (fifth-highest number of Facebook friendships). Data on international *phone calls* (measured in million minutes) from 1983 to 1995 originates from the International Telecommunication Union (ITU) and was retrieved from INA (Louch et al., 1999). Information on *remittances* was obtained from the World Bank (Ratha and Shaw, 2007). Remittances can be defined as "current private transfers from migrant workers who are considered residents of the host country to recipients in the workers' country of origin" (World Bank, 2011, p. xvi). We regard remittances as a type of THC because they are transfers between individuals that "often involve related persons" (IMF, 2005, p. 75) and can thus be understood as expressions of support or solidarity, and ultimately as a form of communication.

In addition to analyzing these eight activity types individually, we are also interested in getting an idea of what the spatial structure of THA looks like *as a whole*. The multiplexity of human mobility and communication, i.e. the variety of ways in which people interact, needs to be addressed as concentrating on single activity types alone may lead to biases (Stopczynski et al., 2014). To do so, we link the activity types in three indices. First, a *THM index*, in which the cell values of the 2010 matrices of the five types of mobility are added up. This simple procedure is reasonable because all mobility networks are based on the same unit of analysis (individuals moving between countries). As shown in Table 2, the weight in the THM index differs drastically by mobility type, with tourists and migrants making up for 82.0 and 16.9 percent, respectively, whereas asylum seekers, refugees,[8] and students taken together account for only 1.1 percent of all THM. Second, a *THC index* is created from the latest available matrix of the three forms of communication under study. This is less straightforward as the units differ between the types of THC (remittances are in US-Dollar, phone calls in minutes, etc.). We deal with this issue by normalizing the units and calculating the average value across the three types of THC, giving each of them the same weight. Third, we create a *THA index* by adding the standardized values of THM and THC, giving a weight of 0.6 to the former and a weight of 0.4 to the latter. The purpose of these factors is to account for the fact that physical mobility requires more effort than indirect communication and should therefore receive more weight. The overall indices should be understood as only providing a tentative impression of THM, THC, and THA as a whole, because (a) we do not include all conceivable activity types, (b) the

[7] The tourism matrices were constructed manually from individual country datasets contained in UNWTO (2014). For a few countries this category is unavailable. In order not to lose these countries, the category "arrivals of non-resident *visitors* at national borders" was used in these instances. In cases where both these categories are missing, the category "arrivals of tourists *in all types of accommodation establishments*" was used instead. Moreover, in some of these datasets, tourism numbers are reported for groups of countries rather than individual nations of origin. In order to keep as many of these figures as possible, numbers were split (in equal proportions) in cases in which only two countries (e.g. 'Australia and New Zealand') were drawn together. As a result, the portion of lost cases drops to less than 4% of all cases.

[8] In some countries' census statistics, refugees are also counted as migrants, while in others they are not (UN, 2012). The UN tries to account for this by including refugees in "most developing countries" as migrants in the migration dataset (Ibd). It is therefore possible that refugees are sometimes counted twice. However their small relative weight (0.8 percent) shows that this issue has little practical consequences for the overall THM index.

size of the weighting factors in the latter two indices is to a certain extent arbitrary, and (c) not all elements date from the same year (although our finding of long-term stability [cf. section 5.2] indicates that older data can readily be used as a proxy). Despite these shortcomings, our indices constitute a significant first step to covering the multiplex nature of THA.

4.2. Methods

In order to determine the spatial structure of THA, we compare the empirically observed probability density distribution of distances r (in km) to the ideal pattern of a power-law function and describe to which extent the two are similar. To do so, we use the *curvefit* module in Stata (Liu, 2010), which provides a goodness-of-fit measure (R^2) and other relevant parameters like the scaling exponent β. However, we cannot just use the raw original observations, because our data is bound to a limited set of possible distances based on the grid of the world's nation-states. On this grid, not every conceivable distance actually exists and, by hazard, certain distances occur far more frequently than others. For instance, not a single country pair in our dataset features a distance of 3,882 km, but there are coincidentally eight country dyads which are 3,883 km apart. This variance does of course not have any substantial meaning and we need to find a way to eliminate such spurious gaps and spikes before running our analyses.[9] The generally accepted solution to this problem is to "bin" the observations, i.e. to aggregate step lengths that lie close to each other (Buchanan, 2008). Ecological studies often use exponentially growing bins widths of size 2^k (with $k = 1, 2, 3...$) to obtain equally distanced observations in log-log graphs (e.g. Sims et al., 2008). Here, by contrast, we use the same bin width at all distances, for two reasons: first, since we concentrate on *trans*national mobility alone, we are unable to observe what happens at short distances, i.e. within countries. Exponentially growing bin widths, however, produce a higher proportion of bins at such short distances, leaving us with an unnecessary small number of usable observations. Second, as this article is mainly targeting a social-scientific audience presumably less interested in technical log-log specifications and more in substantial graphs that illustrate the empirical relations in their actual shape, we show our findings mainly on normal axes (adding smaller log-log insets for the more technical reader). On normal axes, however, constant bin widths make more sense as they appear equidistant. After trial computations with lower and higher step lengths, we decided to use a bin width of 500 km as a reasonable compromise between inflating the variance and overly flattening the distribution. The binning results in a reduction of data points, i.e. the 38,220 raw observations in each matrix are pooled into 39 usable meta-observations. As a robustness check, we partially repeated the analysis with Kernel-weighted local polynomial smoothing using an Epanechnikov-kernel function in Stata's *lpoly* module.[10] This procedure, in which the number of observations remains at 38,220, leads to similarly high power-law fits, suggesting that the selected bin width works well indeed. In the remainder of the article, we stick to the findings from the more parsimonious binning method, which is more recognized in the Lévy-flight literature and has the additional advantage of leading to the same global maximum (500 km) for most activity types, thereby increasing cross-type comparability. The global maximum is relevant since in fitting the power law, we focus on the tail of the distribution (i.e. the part to the right of the global maximum). This in turn is necessary, because, due to our blindness for intra-national activity, we know too little about what occurs at short distances (i.e. left of the global maximum).

5. Results

We first examine the spatial structure of THA based on the latest available year (5.1), then turn to the analysis of longitudinal trends (5.2), and finally compare our findings to theoretical scenarios and results from other studies (5.3).

5.1. The spatial structure of transnational human mobility and communication

Fig. 1 shows the probability density distributions of all types of THA under study at the latest available point in time. Dots represent binned empirical observations while solid lines depict power-law curves fitted to the empirical distributions' tails. The goodness-of-fit is indicated by the R^2 in the upper right corner (0 = no fit, 1 = perfect fit), by which the subgraphs are sorted. The scaling exponent β, placed below the R^2, indicates the steepness of the power-law curve. To additionally illustrate the power-law fit, the insets show the distributions and curves on logarithmic axes (on which the power law by definition takes the form of a straight line along which the observations should cluster), for displacement lengths of $r \leq 15{,}000$ km.

Concerning THM (Fig. 1A), the power-law fit is highest for refuge-seeking ($R^2 = .996$), and just slightly lower for tourism ($R^2 = .982$), asylum-seeking ($R^2 = .951$), and migration ($R^2 = .931$). Only for student exchange does the power law not fit the empirical distribution well ($R^2 = .799$). The spatial structure of student exchange differs from that of the other activity types in that there is a second peak at middle-range distances (approx. 7,000–14,000 km). A closer look at the data reveals that this peak results mainly from large flows of students from China, India, and South Korea to the United States and the United

[9] Note that this problem does not just occur in our case but for any empirically gathered mobility traces, including animal motion. A shark for instance may by coincidence have moved 2.4 m fifteen times but not once 2.3 m.

[10] Local polynomial smoothing is a non-parametric modeling approach, which means that instead of assuming a certain functional fit (e.g. linear, power-law, etc.) *ex ante*, the data "speaks for itself" (Gutierrez et al., 2003). This property is beneficial here, because we want to *first* smooth the data (without imposing assumptions about its distribution) and *then* test the fit of the data to a certain function (namely the power law).

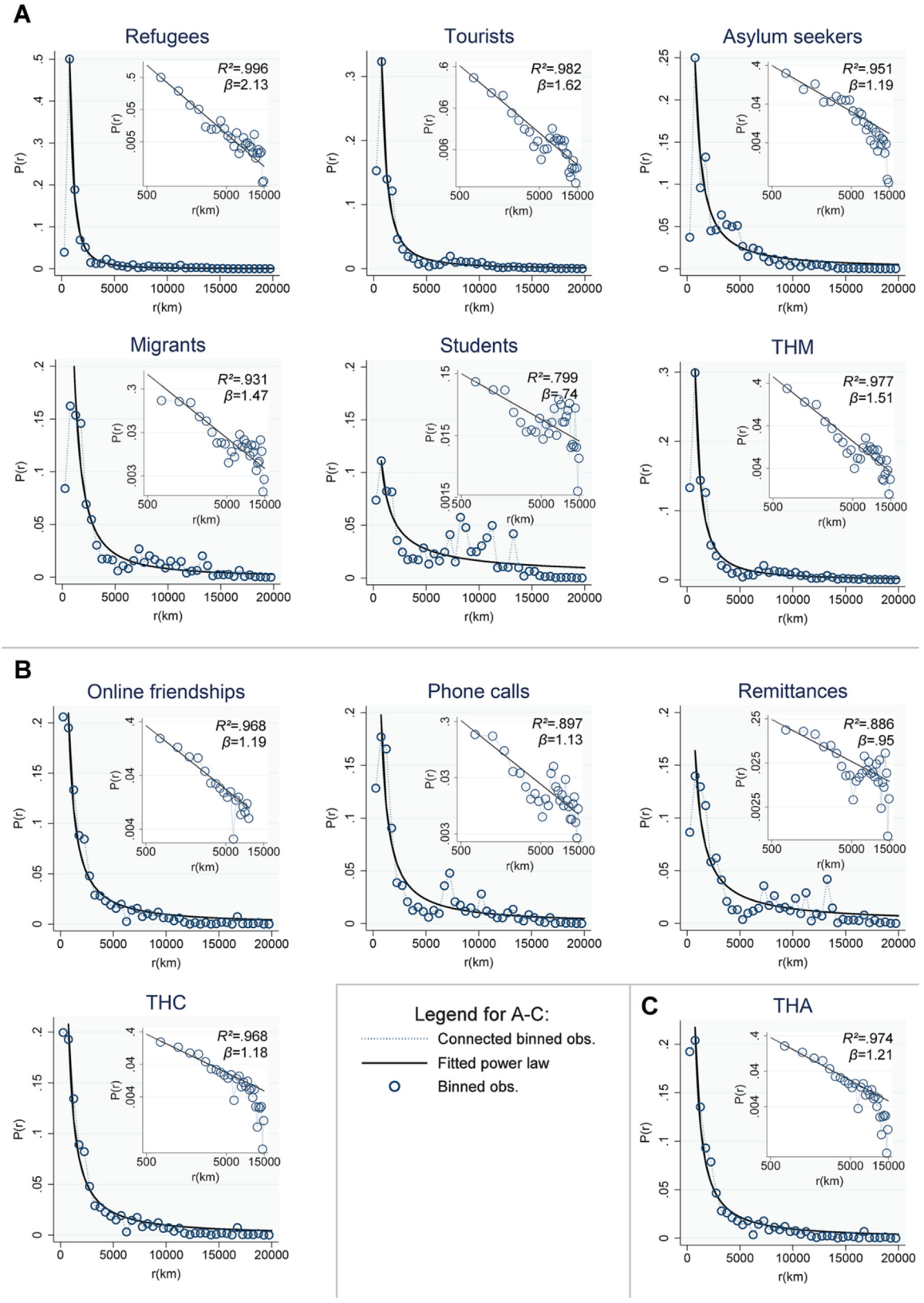

Fig. 1. Probability density functions of THA and their power-law fit.

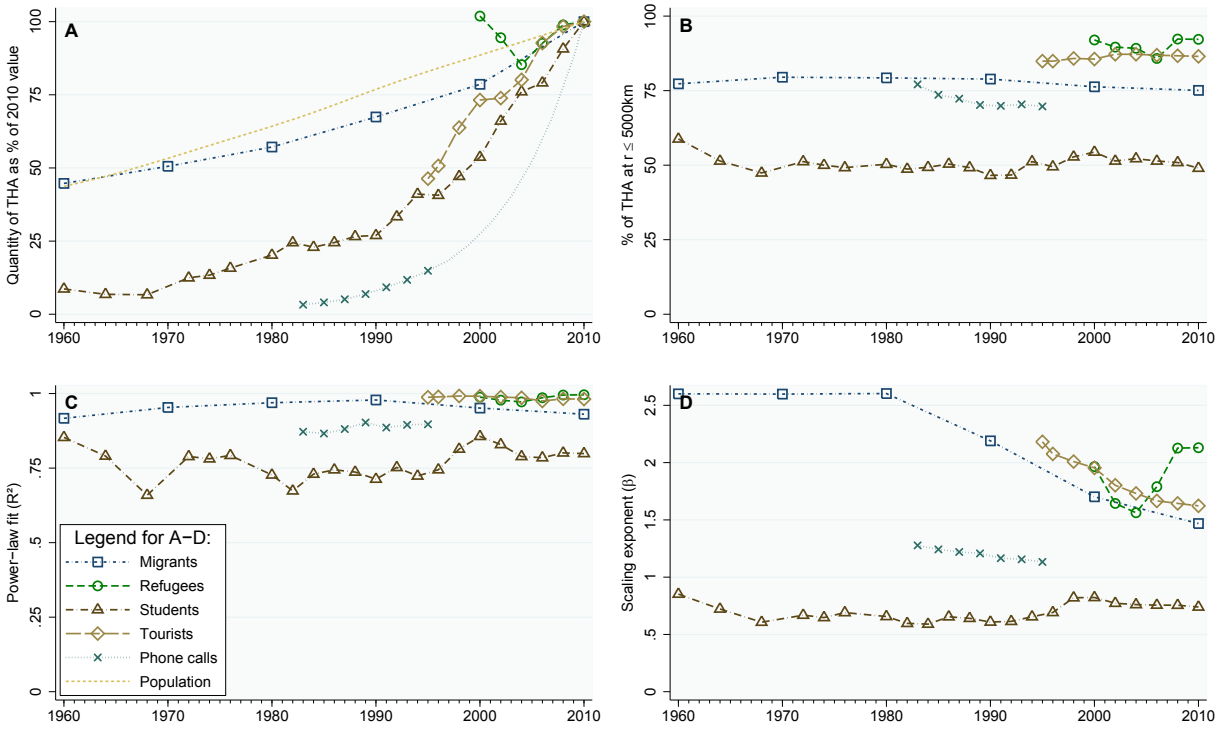

Fig. 2. Trends over time.

Kingdom, which fits our assumption about the role of the global university system's heavy stratification and the related lack of intervening opportunities. The scaling exponent β is highest for refuge-seeking ($\beta = 2.13$), medium-high for tourism ($\beta = 1.62$), medium for migration ($\beta = 1.47$), and small for asylum-seeking ($\beta = 1.19$) and student exchange ($\beta = 0.74$). Apart from the surprisingly low β value for asylum-seekers,[11] the theoretically expected order holds, indicating that type-specific goal-attainment opportunities and available resources help predict spatial structures of human mobility across nation-state borders. THM as a whole also clearly follows a power law ($R^2 = 0.977$, $\beta = 1.51$).

Regarding THC (Fig. 1B), the power-law fit and scaling exponent are highest for online friendships ($R^2 = .968$, $\beta = 1.19$), lower for phone calls ($R^2 = .897$, $\beta = 1.13$), and lowest for remittances ($R^2 = .886$, $\beta = 0.95$). The smaller scaling exponent for analogue phone calls in 1995 compared to digital Facebook friendships in the late 2000s is clearly at odds with the argument that lower communication costs lead to a "death of distance", or, put more mildly, to a *flatter* probability density distribution. Contrary to popular belief, the abolition of monetary costs for overcoming distance does not result in a lesser role of distance in structuring human communication. The overall index of THC also features a high power-law fit ($R^2 = .968$) and the scaling coefficient ($\beta = 1.18$) is only slightly lower than for THM ($\beta = 1.51$), indicating that message-based communication is just marginally less subjected to gravitational forces than physical mobility.

With respect to THA as a whole (Fig. 1C), we again find an excellent power-law fit ($R^2 = 0.974$, $\beta = 1.21$), indicating that most human activity beyond nation-state borders today only spans relatively short distances and genuinely global mobility and communication is still extremely rare. Contrary to popular notions about the detachment of human activity from spatial constraints in the age of globalization in the geography-is-dead debate, the forces of physical space seem to be intact. But is THA today, compared to the past, at least *somewhat* more globalized? To answer this question, we now turn to analyzing trends over time.

5.2. Developments over time

To investigate longitudinal trends, we look at four different indicators: the overall amount of THA (Fig. 2A), the percentage of THA that takes place at relatively short distances (Fig. 2B), the power-law fit (Fig. 2C), and the scaling exponent β (Fig. 2D).

Fig. 2A illustrates that almost all types of THA have seen massive growth over the years. The number of transnationally mobile students (depicted by triangles) grew exponentially from 255,000 in 1960 to 2.9 million in 2010, an 11.5-fold increase.

[11] The unexpected values for asylum-seeking should not be over-interpreted as the number of asylum-seekers is relatively low, making the structure susceptible to fluctuations.

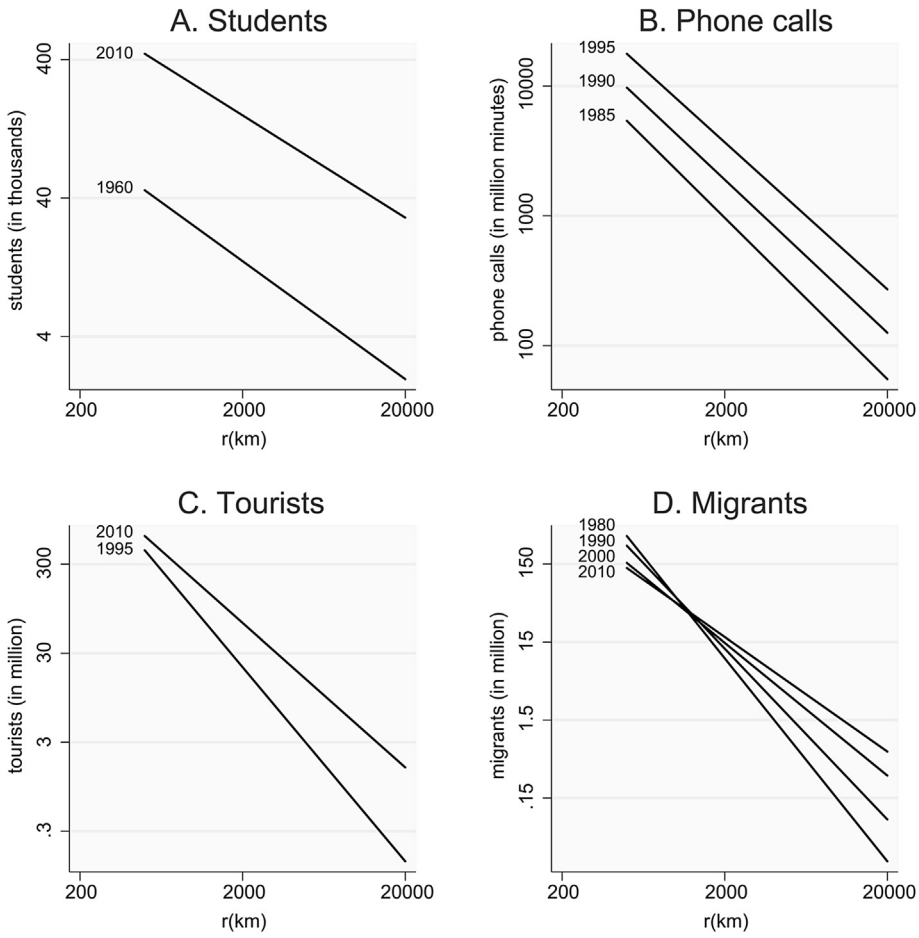

Fig. 3. Log-log plots of THA over time.

Transnational phone-call minutes (depicted by crosses) increased from 12.4 billion in 1983 to 56.6 billion in 1995, rising 4.6-fold in little more than a decade.[12] Similarly, the number of transnational tourists (depicted by diamonds) rapidly grew from 457.6 million in 1995 to 987.3 million in 2010, an increase of 115.8 percent. The number of migrants (depicted by squares) was estimated to be 91.2 million in 1960 and more than doubled (plus 123.6 percent) to 204.0 million in 2010. Only the number of refugees (depicted by circles) does not follow a clear direction over time. All in all, the amount of THA has increased dramatically over the last decades.[13]

By contrast, Fig. 2B–C shows a remarkable degree of over-time stability when it comes to the spatial structure of THA. Fig. 2B illustrates the percentage of THA that takes place at displacement lengths of $r \leq 5{,}000$ km, i.e. at distances shorter than about ¼ of the largest possible distance between two countries. For comparison: the driving distance between Seattle and Miami is 5,400 km. We are thus talking about relatively short distances at the planet scale. The graph reveals two things: (a) the percentage of mobility and communication that takes place below this threshold varies between types of THA, and (b) it remains strongly attached to these type-specific levels over time. For students, the percentage of stays abroad at distances of $r \leq 5{,}000$ km remained at about 50.6 percent (standard deviation $\sigma = 2.6$ percent) over a period of fifty years. Similarly, in every decade from 1960 to 2010, about 77.7 percent ($\sigma = 1.8$ percent) of migrants moved these relatively short distances. At nine measured time points between 1995 and 2010, the fraction of tourists that went such short distances varied closely

[12] For phone calls, post-1995 values are extrapolated by fitting an exponential trend line ($R^2 = .998$) of the form $y = 1E + 10e^{0.13x}$, where x is 1 in 1983, 2 in 1984, etc. This assumption of exponential growth, which leads to an estimate of 380.9 billion minutes for 2010, is conservative given that TeleGeography (2014, p. 2) estimates the international call volume to exceed 400 billion minutes in 2010.

[13] One may want to consider that the world population also increased over time: in the 196 countries under study, it grew from 3.0 billion in 1960 to 6.9 billion in 2010 (short-dashed line in Fig. 2A). Student mobility, tourism and phone calls grew at a faster rate, but, contrary to what catchphrases like "age of migration" (Castles and Miller, 2009) suggest, the relative strength of migrants as a share of the world population decreased during the 1960s, '70s, '80s, and '90s, and only in 2010 reached the level it had in 1960.

around 86.2 percent ($\sigma = 0.9$ percent). For refugees, the share was about 90.2 percent ($\sigma = 2.5$ percent). Only phone calls (mean: 71.9 percent, $\sigma = 2.7$ percent) appear to witness a slow but constant drop – yet the development of refuge-seeking during the 2000s shows how quickly such a trend can reverse. Overall, the consistently low standard deviations highlight the robustness of the spatial structure of THA over time. Similarly, the power-law fit (Fig. 2C) remains remarkably stable. For phone calls, it remains solid at about 0.886 ($\sigma = 0.014$). In the case of migration, it varies steadily around 0.950 ($\sigma = 0.023$). Tourism and refuge-seeking remain at the ceiling, with fits of 0.986 ($\sigma = 0.005$) and 0.986 ($\sigma = 0.009$) respectively. For student exchange there are some ups and downs, but all in all the power-law fit oscillates around 0.767 ($\sigma = 0.052$). Thus, the power-law fit is another indicator of the startling long-term stability of the spatial structure of THA.

Per contra, Fig. 2D shows a mixed picture when it comes to the development of the scaling exponent β. For tourists and migrants (which together represent 98.9 percent of all THM) a steady drop in the size of β can be observed. For migration, this decrease is first visible in the 1980s, after two decades of absolute stability. With respect to phone calls, we see only a slight gradual decrease over time. Concerning refugees, β first drops between 2000 and 2004, but then increases again until 2010. For students on the other hand, the scaling exponent remains more or less stable at a low level. This finding of partial stability and partial flattening can be examined more closely in log-log plots (Fig. 3).

The graphs in Fig. 3 show the best-fitting power-law curves (which form straight lines here, as both axes are logarithmic) for the spatial structures of the four types of THA with a clear β-value trend, at various points in time. To visualize both absolute growth and relative shifts, the y-axes now show the actual amount of mobility and communication taking place. Remarkable differences become apparent: for students and phone calls (Fig. 3A–B), the fitted power-law curves form parallel lines that just move upwards on the y-axes as the number of students and phone-call minutes increases over time. In other words, student exchange and phone calls grow at about the same rate at all distances over time, thus retaining their spatial structures' shapes. For tourists and migrants (Fig. 3C–D) however, the picture looks different. Here, the lines still move upwards, but also become flatter over the years. This difference shows that no universal trends hold for all types of THA, underlining the fruitfulness of our comparative approach.

At first sight, there appears to be a contradiction between the over-time stability observed in Fig. 2B and the shifts unveiled in Fig. 3C–D. Are tourism and migration "globalizing" over time, or not? The seeming paradox can be resolved by reminding oneself that the straight lines in Fig. 3 are only imaginary – in reality (i.e. on regular axes) they form heavily bended curves. Shifts that are meaningful in size only occur within the short-distance range (i.e. at displacement lengths of $r \leq 5{,}000$ km), leaving the share of long-distance THA practically unaffected. Therefore, these changes should rather be taken as signs of regionalization (i.e. gradual extensions of the spatial reach of THA at a regional scale) than as evidence for globalization. At the planet-wide scale, stability prevails – even for tourism and migration (as visible in Fig. 2B).

5.3. Relation of our findings to theoretical scenarios and other studies

So far, we have mainly adhered to the Lévy-flight debate's approach in our analysis and only made allusions to the geography-is-dead debate en passant in the longitudinal analysis by assuming a "flatten*ing*" world. In this last analytical step, we examine what would happen if the geography-is-dead debate's statements were understood in a stricter sense and distance played no role *at all* anymore. To do so, Fig. 4 compares the empirically observed spatial structure of THA (our overall index, depicted by the solid line) to various hypothetical scenarios.

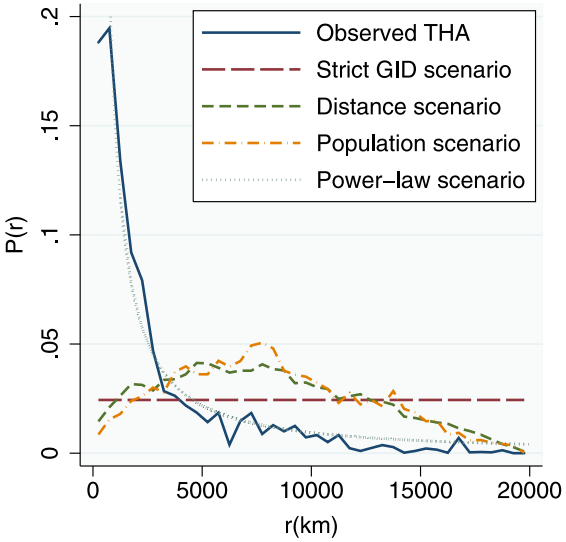

Fig. 4. The relation of empirical THA to theoretical scenarios.

The first one, the *strict geography-is-dead scenario*, shows what the distribution would look like if the probability of activity to occur would literally be the same at all distances (a "flat world" in Friedman's terms). The second one, the *distance scenario*, refines this assumption by taking the actual geographic distribution of country dyads in the world into account. As short and long distances are empirically less common than middle-range distances, the relation would be reverse-u-shaped if the amount of activity was the same between each of the 38,220 existing country pairs (reminiscent of Marx and Engels's "universal interdependence of nations"). The third one, the *population scenario*, is a further refinement that takes into consideration that countries differ by population. It shows what would happen if each individual in each country had the same chance of going to any other country independent of its geographic location (akin to Toffler's new nomads who "leave the physical structure behind"). It is immediately apparent that none of the three scenarios comes anywhere near the actual data. In reality, far more activity occurs at short distances and far less at longer distances than the geography-is-dead hypothesis in its strict sense would suggest. The dotted power-law line, which we include here again for comparison, shows that the Lévy-flight is much better at realistically representing the spatial structure of THA than any geography-is-dead scenario. Again, we find that distance is not dead at all.

Finally, we are also able to compare our findings to those of other studies at lower geographic scales and for different species. Concerning local human mobility, Hägerstrand (1967) finds a scaling exponent around $\beta = 1.7$, while Gonzalez et al. (2008) similarly report $\beta = 1.75$ half a century later. For national human mobility in the US, Brockmann et al. (2006) specify $\beta = 1.59$. Our value for transnational human mobility is only slightly lower with $\beta = 1.51$ and practically identical to the $\beta = 1.50$ reported by Noulas et al. (2012) for the global structure of LSS log-ins, which may be taken as an indicator of robustness. For a set of marine predators, Sims et al. (2008) found $\beta = 2.12$, whereas for spider monkeys, Ramos-Fernández et al. (2004) name $\beta = 2.18$. This consistent ranking of the scaling exponents could indicate that while mobility follows Lévy-flight patterns at all geographical scales and across many species, the scaling exponent is smaller (i.e. longer distances are relatively more common) in humans than in non-human species and at higher geographic scales than at lower geographic scales. We leave this impression to further scrutiny by future research.

6. Discussion and conclusion

Starting from contradicting propositions of hitherto disconnected debates in the natural and social sciences, this article analyzed the planet-scale spatial structure of transnational human activity (THA) comparatively across eight different types of mobility and communication in its development over time. The findings can be summarized as follows:

1. **Overall picture:** The planet-scale spatial structure of transnational human mobility and communication is similar to that of animal motion in that it can be approximated by Lévy-like power-law functions. This implies that contrary to prevailing social-scientific accounts, geography is not "dead." The large majority of transnational activity still occurs at short distances and global mobility and communication continues to be scarce.
2. **Mobility:** Scaling exponent and power-law fit differ by type of mobility, being highest in refuge-seeking and tourism and lowest in student exchange. This pattern suggests that the availability of opportunities for attaining type-specific goals as well as the resource stock disposable on average to the individuals engaging in a specific mobility type play a role in determining the precise shape of the spatial structure.
3. **Communication:** Distance is stronger in determining online friendships in the late 2000s than analogous phone calls more than a decade earlier. This finding debunks the popular myth that the newly-formed *possibility* to telecommunicate worldwide free of charge also means that *factual* communication occurs independently of distance.
4. **Trends over time:** Despite dramatic increases in the absolute amount of transnational mobility and communication over the years, the Lévy-flight pattern remains intact and remarkably stable over time. Longitudinal change occurs only for some types of THA and predominantly at short distances, indicating shifts at the regional level rather than globalization.

This study aimed at filling a gap in the natural-scientific Lévy-flight debate by conducting the first encompassing spatial analysis of planet-scale human activity and at complementing the social-scientific geography-is-dead debate by subjecting its propositions to a rigorous empirical test. The analysis revealed that the Lévy-flight model works well, whereas the death-of-distance arguments do not hold under close scrutiny. Geography still shapes the patterns of planet-scale human activity. Where humans interact across nation-state borders, they are very likely to do so with neighboring countries and within the world regions they live in. The discrepancy between this finding and popular accounts of globalization – from McLuhan's "global village" to Friedman's "flat world" – may indicate that we as humans tend to overestimate our capability to transcend nature. Despite the profound historical, technological, socio-economic, and infrastructural revolutions that took place during the last half century – from the end of the bipolar world system after the fall of the iron curtain to the rise of mass tourism and the dawn of the internet age – the overall patterns of human mobility remain largely unchanged, bound to the same natural laws as the motion of all kinds of species, from plankton to penguin.

For the natural sciences, our finding that the Lévy-flight model is not only able to capture displacements of foraging animals, but also to describe how humans and their messages travel around the world raises new questions about the aptitude of existing theorems. In specific, does the argument that Lévy-flight patterns are the result of random food search optimization (Viswanathan et al., 1999) still make sense? Transnationally active humans have all kinds of goals and are hardly

random searchers but use knowledge about their environment to *decide* where to go (Rhee et al., 2011; Song et al., 2010). In the end, however, this discrepancy does not make much of a difference. Whether moves are instinct-driven and spontaneous (shark) or information-driven and long-planned (migrant), the power law applies. The scale can be centimeters (plankton) or the surface of the whole earth (transnationally active humans) – the spatial structure remains alike.[14] Even for mobility types associated with entirely different motives (just think tourism vs. refuge-seeking), the Lévy-like pattern is found. This almost universal applicability of the power-law pattern suggests that much broader mechanisms than food search optimization are at work. In our conceptualization, we proposed variance in resource stock and type-specific opportunities for goal-fulfillment as primary explanatory factors. This model is superior to the random food search optimization hypothesis in at least two ways. First, our two factors apply universally: any living being is endowed with a certain research stock and all goals species pursue over and above food search (exploring, playing, mating, searching for shelter, etc.) are covered. Second, while the random search theory only allows to compare empirical deviations from the theoretical ideal ($\beta = 2$), our model allows for a truly comparative approach along the dimensions of the two central explanatory factors. Here, we made use of this feature to compare eight types of human mobility and communication, but in principle the model could be applied similarly to conduct comparisons between all kinds of species.

For the social sciences, our analysis has a variety of implications, too. A first contribution consists in the clarification of what "transnational" actually means. As discussed above (section 3), the term is per se vague due to its lack of a "closing dimension" (Delhey et al., 2014). Here, we showed that transnational activity features a gradual *empirical* closure that takes the form of a specific mathematical function – the power law: transnational activity is most common in close proximity to its origin, becomes scarcer at a declining rate as distance increases and ends in a long tail of rare activity over planet-scale distances. This means that the vast majority of transnational activity occurs *within* world regions, not at a global scale. Consequently, the traditional practice of equating "transnational" with "global" (e.g. Nye and Keohane, 1971, p. 332) is deceptive.

Closely connected to this point, our findings demand for reconsidering the usefulness of the term "globalization." The "globalization fever" (Wimmer and Glick Schiller, 2002, p. 321) that broke out among social scientists in the 1990s has etched the idea of a "shrinking world" deeply into the collective consciousness. Our analysis, however, shows that – at least with regards to human mobility and communication – such ideas are in large part mythology. For no type of mobility or communication did the share of long-distance (i.e. "global") activity increase over time. We as humans did not become more "global" in the course of the last decades, we rather became more *mobile* in general, i.e. we move more *at all distances*. Thus, it would be more adequate to speak of "mobilization" than of "globalization."

Where moderate shifts occur (as for tourists and migrants), they take place predominantly at relatively short distances ($r \leq 5{,}000$ km), i.e. within world regions. Thus, change in the spatial structure of human mobility and communication over and above the general growth at all distances is better interpreted as "regionalization" than as "globalization." What is more, the very finding that transnational mobility and communication follows a Lévy-like power-law pattern implies that cross-border interaction takes place to an overwhelming extent at short distances within regions, making regional integration a much likelier outcome than global integration. Hence, our analysis could be of interest to several social-scientific fields that utilize transnational social interaction as an indicator of regional integration, from the Sociology of Europe (Delhey, 2004; Mau, 2010; Recchi, 2015) and the Comparative Sociology of Regional Integration (Deutschmann, 2015, 2016) in sociology to transactionalist EU Studies (Kuhn, 2011, 2015) and Comparative Regionalism (Warleigh-Lack and Van Langenhove, 2010) in political science.

More generally, our results highlight the necessity to strive for grounded empirical research instead of just relying on intuitive ideas and well-worded claims such as "death of distance." They also underline the fruitfulness of taking trends in other scientific disciplines into account. Mathematicians, computer scientists, and ecologists can enrich the work of social scientists and *vice versa*. With this study we transcended traditional disciplinary boundaries, but we also crossed another well-guarded conventional border by comparing human with non-human animal behavior. Such comparisons are still extremely uncommon in quantitative social research, despite the recent "animal turn" (Ritvo, 2007) in the social sciences and humanities. Some observers may still see the idea that humans move or behave like sharks and plankton as strong or even offending, not just because humans are traditionally seen by some as the "pride of creation," but particularly because there is a tendency to attribute humans a degree of agency and intelligence that is usually denied to other species. Against this segregative perspective, our analysis shows that such comparisons can reveal astonishing similarities between human and non-human animal behavior. With respect to spatial mobility patterns, our results clearly show that there is no qualitative difference between humans and other animals. At best there are differences in scale and gradient; the power-law structure however is universal.

Thus, taking a step back to look at the overall picture, this overwhelmingly strong bondage of people's mobility and communication to the laws of nature also raises questions about human agency. Do we all just follow fixed paths? Is free choice an illusion? For centuries, the seeming contradiction between apparently independent, freely made individual-level decisions and uniform aggregated macro-level behavioral patterns has moved philosophers and sociologists, from Kant (1824[1784], p. 385) to Durkheim (2005[1897]). Here we are again facing such a situation, and again the question arises what is left for free will and social constraints if our collective behavior is predictable by a simple mathematical function (i.e.

[14] But see our discussion of apparently meaningful variance in scaling exponent size between species and scales in section 5.3.

the power law)? The answer is: most likely a lot. We just have to relinquish the global macro-perspective and "zoom in." For example, the deviation of student exchange from the power-law pattern indicates that institutional stratification matters. Furthermore, our comparative analysis of different mobility types allowed for a first glance at social inequalities and the role of class position: a larger endowment with resources clearly seemed to affect the spatial mobility pattern. However, to analyze more thoroughly how spatial structures differ by social strata, future work would need to combine information about where people move with more attributes about these people (education, income, skill type, etc.). Doing so could help establish whether the observed power-law patterns are only systemic, resulting from a combination of poor individuals moving/communicating over short distances and rich individuals moving/communicating over long distances, or whether they hold for all social classes (or even individuals), most likely with differing scaling exponents. Past research has already tackled the social stratification of transnational activity (Delhey et al., 2015) and analyzed class-specific forms of transnationalism, from blue-collar workers (Lutz, 2011) to elites (Schneickert, 2015). So far, however, differences in the *spatial* structure between these class-specific forms of transnational activity have been neglected. Another interesting path would be to comparatively examine the spatial structure separately for the world system's center and periphery or by region. Moreover, one could try to compare the over-time stability of THA with the longitudinal systemic stability found in other domains, e.g. in the tripartite global wealth structure (Babones, 2005). In sum, there are many paths for further research, some of which of course depend on the availability of better data.

Beyond its mere academic contribution, our analysis also shows how distorted and misleading recent right-wing politicians' claims concerning the influx of migrants, asylum-seekers, and refugees into Europe and other rich parts of the world are, from "We can't take everybody in"[15] to "We can't save the whole world."[16] A glance at Fig. 1 suffices to see that such statements are completely detached from reality: only a tiny fraction of all refugees and asylum-seekers heads towards distant destinations such as Western Europe. In large part, they move to neighboring countries (e.g., Lebanon, Turkey, Jordan, and Iraq in the case of the Syrian civil war). From the reversed angle, however, this finding implies that the bigger part of refugees does not reach the richest countries but tends to end up in places where citizens and governments are often struggling themselves. Global governance and migration policies could improve their effectiveness by taking this finding seriously. For instance, the general assumption of a power-law distribution of moving persons in space might help distribute humanitarian and development aid more efficiently in the wake of natural disasters, war, or repression, when precise information about victims' current *factual* location is scarce. Future research may seek to link our findings to other issues that are heavily intertwined with cross-border activity, from global food supplies, wealth inequalities, and transportation to electricity transmission and the spread of epidemics. We share the hope of Hui et al. (2010) that new insights into how we as humans move and communicate worldwide may help tackle such pressing global problems.

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[16] Secretary General of Bavaria's ruling conservative party CSU Andreas Scheuer, 20 July 2015 (PNP, 2015). In the same vain, Bavarian Finance Minister Markus Söder, 3 October 2015 (BR, 2015).

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