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Effects of Social Capital and Migration on Health Outcomes among Residents of Slums in Delhi, India

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Abstract

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By Patrick Mayne

The growth of cities in the global south, driven in part by unprecedented levels of migration from rural areas to urban centers, has emerged as a major area of public health concern. Additionally, previous research has shown that social capital and residential segregation in urban areas may have significant impacts on a wide variety of infectious and non-infectious health outcomes. The present research seeks to measure the effect of both social capital and residential segregation on febrile illness among rural-to-urban migrants living in slums in Delhi. Data analyzed were collected as part of the Delhi Life of the Urban Poor (DUP)/Delhi Voters Project (DVP) from 2009 until 2011. Two multilevel mixed-effects logistic models were fitted, one for adult and one for child outcomes. These models examined the effects of household migration, household social capital, and slum-level measures of residential segregation (in terms of language, state of origin and religion) on the odds of reporting more than two incidents of febrile illness in the past year. For adults, being born outside of Delhi was a significant predictor of higher incidence of illness among those with lower levels of social capital (OR = 2.58, 95% CI: 1.11 – 6.01), while there was no significant effect among those with higher levels of social capital. Among children, there was no similar effect of place of birth on health outcomes, though a household history of more frequent moves was a significant predictor of higher incidence of illness (for one additional move, OR = 1.15, 95% CI: 1.001 – 1.31). Neighborhood diversity was only significantly associated with illness among children, with greater linguistic homogeneity predicting higher incidence of illness (OR = 1.01, 95%CI: 1.00 – 1.02). This study echoes previous findings that rural-urban migration may place migrant populations at special risk for adverse health outcomes, but finds that these effects, and thus programs designed to address them, differ between adult and child populations.

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Introduction

The National Capitol Territory of Delhi (NCT Delhi) has grown by more than three million people in the past decade, translating to a growth rate of 21% (1). Demographers and policymakers have highlighted the potential negative consequences of this rapid growth in Delhi and other Indian cities, including concerns about the impact on environmental degradation; increased strain on already overburdened infrastructure; increased transmission of infectious disease; and the economic consequences of congestion within these urban areas (2–4).

Further compounding the consequences of such rapid urban growth is the issue of increased economic, social and health inequalities. Rural poor migrating to Delhi, often moving into one of the city's hundreds of slum colonies, are responsible for a large proportion of urban population growth over the past decade (5). While most migrants report moving from one area to another to take advantage of greater opportunities for employment, education, healthcare, and a better overall quality of life (6,7), researchers and advocates have reported that recent rural-to-urban migrants, and especially those living in urban slums, face daily barriers to the realization of these opportunities (8,9). These barriers may take the form of linguistic difficulties inhibiting efficient communication with health service providers; discrimination based on class, caste, religion, or place of origin; economic hardships; or lack of knowledge of services available near the new residence (8,10–13). In addition to barriers preventing utilization of services within the urban environment, chronic stress in the urban context and social dislocation associated

with migration from a close-knit rural community to a metropolis of over 15 million people are frequently associated with poorer health outcomes (14–17).

The formation of social capital, or meaningful and supportive networks which may provide tangible or intangible benefits to those involved (18–20), may do much to alleviate many of the negative harmful exposures associated with urban living that have been described above. Information flows from more established residents to more recent arrivals in a community may speed assimilation into local structures and ease migrants' access to services provided in the new city (21). Similarly, social support in the form of childcare, transportation, employment referrals, or personal loans, among others, has been shown to increase the utilization of available health and social services by mitigating the immediate costs borne by an individual or household (11,12,21). Finally, social capital itself is shown to decrease risk of disease, potentially through the reduction in chronic stress experienced by individuals with strong social support systems (22).

Chain migration—migration directed and facilitated by strong kinship and social ties between those living in an urban area and people in their (rural) place of origin—has been shown to lead to strong social capital in urban receiving areas (23). This process in many cases also leads to the emergence of migrant enclaves within a host city. These enclaves are by definition segregated from the surrounding city, often sharing a language, religion, or culture which is wholly distinct from the majority of the city's residents. While social support and social capital may be higher in these areas due to the kinship-based networks which led to their creation, this type of segregation and community-level isolation has been seen,

especially in American cities, to have a deleterious effect on the health of inhabitants (24). Within these areas it might be expected that linguistic and knowledge barriers to healthcare, among others, may be compounded, leading to overall poorer health outcomes than would be expected in similar, but less insular, populations. To date, it appears that there is little research in the global south measuring the association between residential segregation, and especially migrants' enclaves, and health.

Review of the Literature

Urbanization and health

The phenomenon of urbanization is understood to be a process by which population shifts from rural areas to urban areas, either as an increase in the absolute number of people living in urban areas or as the proportion of the total national population living in cities (25). This demographic shift is driven by a combination of migration from rural areas to urban areas, and an increasing number of births within urban areas, though the overall contribution of each of these mechanisms to urban population growth is unclear and varies widely across countries (5). Cities around the world have grown from housing less than thirty percent of the global population in 1950 to housing of over fifty percent of the population in 2011, being the home of more than 3.5 billion people (26).

Researchers have enumerated a number of pathways by which urbanization and the urban environment might impact health. Vlahov and Galea have conceptualized the urban environment impacting health in two main ways (25). First, the process of urbanization itself, which in their framework is the dynamic process by which cities become more densely populated, more complex, and cover a larger extent, may affect health by placing strain on the provision of infrastructure and services or by changing the socio-economic environment of an area. Second, cities impact the health of their inhabitants through the complementary concept of urbanicity, which is the characterization of an area as more or less urban at one

point in time, and encompasses themes such as air pollution, traffic congestion, and opportunities for recreational activities. This conceptualization of urbanicity as a continuum of urban exposures has been operationalized through a number of studies which have attempted to define and "urbanicity scale" and correlate this concept with population health outcomes (27–30).

Within the theoretical framework proposed by Vlahov and Galea, numerous studies of health impacts have been undertaken, around the world but especially in low- and middle-income countries. In particular, much work has been done on the impact of urbanization, and especially greater population density, on the transmission of infectious disease. Some studies have found increased rates of transmission of HIV and tuberculosis in urban areas, relative to rural areas, due to greater numbers of contacts between individuals and greater population mobility (3,31–33). Similarly, the rapid growth and high density of urban populations has, as noted above, posed significant challenges to urban infrastructure, leading to sub-standard or nonexistent sanitation systems, and increasing the rates of diarrheal disease within some urban populations (3,33–35). Urban environments and population density have also, in some cases, been shown to provide favorable conditions for the transmission and amplification of vector-borne disease, both through an improved environment for the reproduction of vectors and through increased population mixing, leading to disease spread over a larger area than would otherwise be expected (36–38).

Social changes and changes in human behavior associated with the urban environment have also had significant impacts on the health of urban populations.

A rise in sedentary lifestyles, and an increased consumption of high-fat, high-sugar convenience foods, has been linked to higher rates of obesity and obesity-related diseases in cities than in rural areas (39–43). The urban environment itself, and its associated congestion, noise, and stress, have also been seen to negatively impact mental health and overall well-being within cities (14,15,44–46). Additionally, some researchers have found that urban environments in and of themselves are associated with lower social capital and less supportive informal safety nets, thus making individuals more susceptible to negative external shocks, such as adverse health effects or the loss of employment, though evidence of this effect has been contradictory (16,17,47).

Recent research has also focused on the positive impact of urban living on health. Food security has been shown to be more easily attained in urban areas relative to rural areas, thus leading to a decrease in the incidence of malnutrition, and especially micronutrient malnutrition in urban residents (43,48). In many cases this effect can be explained by higher incomes and higher socioeconomic status (SES) in urban areas (49,50). Healthcare services are more easily provided, and more readily utilized, within densely populated urban environments where average distances to a service provider are greatly decreased relative to rural areas (51–53).

In spite of the undeniable and growing importance of cities in housing the global population, research into the effects of urbanization has been hampered by a number of methodological difficulties. First and foremost, the definition of "city" or "urban area" is poorly defined, and, in international comparative studies, this definition is rarely standardized across countries (25,54). For this reason, such

studies must be interpreted with caution. The definition of a city may include reference to the local population density; absolute population within an administrative boundary; local characteristics such as connection with public utilities or the proportion of the workforce engaged in non-agricultural activities; the designation of certain administrative units as urban by the central government; or any combination of these (25). Recent research focusing on remote-sensing data on land use and estimated population density has produced a standardized and theoretically generalizable definition of urban areas (55–57), though thus far these approaches have yet to be extended to the point where they may provide fully comparable data between countries.

In addition to problems of measurement, research into the health effects of urbanization is limited by the difficulty in establishing what the health status of a population would have been had there been no urban exposure, while keeping all other conditions identical[1]. As a randomized controlled trial allocating individuals or households to urban or rural areas would be unethical, research on urbanization relies on observational studies comparing rural and urban populations (41,49,58,59), or comparing rural-urban migrants to non-migrant populations in the rural place of origin or the urban host area (21,44,60). These studies are therefore unable to account for unobserved differences in attitudes, social support, and access to tangible and intangible resources which are likely to differ substantially between rural, urban, and migrant groups. An important source of bias in these studies is the "healthy migrant bias", where it is expected that those able to complete a migration

[1] This criticism applies equally in the case of the study of migration and health, which is discussed in more depth below.

are the healthier members of the sending population, and thus migration itself may be a driver of health inequalities between geographically-distinct populations (61–63). Similarly, differences in known predictors of health such as income, education, and desire and ability to utilize healthcare may vary significantly across rural and urban areas, thus confounding the association between urbanicity and health outcomes.

Migration and health

Rural-urban migration, a principal driver of the growth of cities, has itself been found to be a significant predictor of healthcare utilization and health outcomes for migrants as well as individuals residing in both the respective sending and receiving communities. While the term "migrant" is often conflated with the (urban) poor, it is by no means true that all migration is among poor populations, or as a result of poverty (64). The vast amount of migration and health research, however, focuses strongly on migrants of lower SES, as these populations are thought to be the most vulnerable to negative health outcomes. This vulnerability stems from a number of factors simultaneously affecting those living in urban poverty and away from close kinship networks: demographic factors, including morbidity, mortality or absence of income earners from the household; political and legal factors including insecure housing tenure and (at least in the case of China) lack of a free right of residence outside of the (rural) place of origin; social factors related to the necessary changes in social structures as a consequence of migration; environmental factors including

housing on marginal land and risks of injury in the workplace; and economic factors related to the often limited earning potential of migrants (65)

Many of these factors are common to the urban poor, as discussed in the previous and following sections, though at least the demographic and social factors deserve special mention in this section. While it has been assumed that both internal and international migrants represented a population with an exceptionally high birth rate (65), a large body of research has shown that migrants' fertility patterns (as well as health statuses and demographic characteristics) are usually intermediate between those of the sending and receiving populations, and that, subject to acculturation and assimilation (discussed below), these patterns rapidly come to resemble those of the receiving population (66–68).

Social disruption as a result of migration and its health effects have been well characterized in the literature, especially with respect to mental health outcomes. In general, it has been found that migration from a rural to an urban area results in a substantial disruption of normal social networks, with migrants consequently having lower social capital than non-migrants in either the sending or receiving area (69–71). This lack of social capital is then associated with decreased resilience and increased risk of adverse mental health outcomes, usually manifested as anxiety or depression, in migrant populations (72,73). Similar negative health effects across a variety of physical health measures have also been found among migrants (44,65,70,74). The pathways by which social capital among migrants is associated with health outcomes, including both infectious and chronic disease, however, are

relatively less understood, though it is assumed that chronic stress plays a significant role (60).

The measurement of social capital among migrants is in general measured by the degree, type and geographic center of the migrant's personal (egocentric) social network, which is itself highly indicative of the stage of acculturation of the migrant in the receiving area (75). In general, it is assumed that migrants with relatively stronger social ties in the receiving area exhibit greater social capital and a greater level of assimilation. These types of network measures have been associated with a variety of health outcomes, including lower incidence of diarrheal disease, greater utilization of antenatal care and improved neonatal health (21,76,77).

Slums and health

The definition of a slum settlement is not clearly defined in the literature. UN-HABITAT eschews a community-level definition, instead narrowly defining the slum household as one lacking in access to at least one of five essential elements: improved water, improved sanitation, security of tenure, durability of housing, and sufficient living area (78). This definition was created specifically for the convenience of measurement and funding agencies, as the measures here are of the type generally reported in household-level datasets (79). Others define a slum settlement explicitly as a community or impoverished area, such as Ward who describes it as the "squalid environs and pathological social conditions of the residential quarters of the poor" (80). These definitions delimit the extremes of the definition, as other writers focus on much more specific localities, side-stepping the

issue of slum definition almost entirely (81). The deployment of the emotive term "slum" as a descriptor of specific places in itself has been seen as a political and marketing tool, both lauded and criticized, but generally recognized as necessary for policy formation related to these localities (82).

In determining what constitutes a slum in a general sense, a number of authors favor an approach that takes into account the genesis and histories of slums. Doran & Landis cite the "filtering" hypothesis which seems to explain the creation of many slums in rich countries—affluent residents of cities move further out as the city grows, resulting in the familiar suburban "donut"—while also describing the historical conditions which may lead to more purpose-built slums, as in the case of Over-the-Hill in Nassau, Bermuda, which developed originally as slave quarters in the late 18th century (81). Modern slum formation is generally described in terms of occupation or invasion, without formal tenure, of either public or private land, which generally marginal or ecologically unsound, by poorer migrants to large cities (83,84). Analyses of slum formation tend to cite the interrelated issues of inflexible zoning policies, housing market inelasticity, lack of liquidity in real estate markets, poor enforcement of existing regulations and inadequate public provision of land as key determinants of slum formation. Under these circumstances, squatter settlements, which may range in quality from homeless encampments to cement and cinderblock houses, tend to expand in order to provide housing to meet growing demands (9,83–86).

Poor health outcomes are widely documented among persons living in slums around the world, and are most readily linked to both household-level material

deprivation and the lack of basic infrastructure provision at the community level. Water and sanitation services, specifically, are generally insufficient in slums (34). Many areas have fewer than one toilet per 600 residents, leading to high levels of open defecation and therefore environmental fecal contamination (9). Lack of official access to water sources leads to a large incidence of "tapping" in and around slums: residents dig up and break into municipal water supply pipes to remove water either directly or through additional piping. This practice leads to a number of adverse health outcomes, both in the slum itself and in the broader city. First, because of the bottleneck in supply (usually, only one water outlet emitting water for only a few hours per day), residents of slums use up to two-thirds less water than non-slum residents of the same city, leading to severely constricted hygiene practices (87). Second, these breaches in pipes, which often run through sewage drainage ditches, allow the entry of pathogens into supposedly clean drinking water, especially during frequent periods of reduced water pressure. This contamination affects residents of the entire city, which must boil water or risk waterborne diseases such as cholera, typhoid, and *E. coli* infection (88,89). Water and sanitation access is systematically denied to slum areas due to official refusal to recognize the areas as legitimate (9,90), thus directly contributing to poorer health outcomes across the city.

Additionally, the unplanned nature and high density of these urban areas has been associated with higher levels of unintentional injury in slum populations (91,92). Other health indicators often associated with poverty are highly prevalent in slums, including respiratory disease (93), malnutrition (94) and neonatal

morality (95), while access to adequate healthcare is in general severely limited, due to geographic, economic and social barriers (95–97).

There is conflicting evidence, however, on whether slum areas are in and of themselves causally related to overall lower health outcomes, or if the observed association disappears once confounding by SES is taken into account (15,98,99). While slum-specific characteristics such as lack of legal tenure clearly have direct implications for many food- and waterborne diseases as described above, for most other types of disease, the pathways are less clear. High population density, low building quality, and indoor combustion of biofuel sources may lead to adverse health outcomes especially in slum developments, but these conditions and behaviors are by no means exclusive to slum areas, and are highly prevalent in non-slum poor areas as well, including Chinese urban villages (100–102). As such, reasonable approaches to improve health outcomes among the urban poor and among residents of slums in particular must address social, economic and environmental determinants of health, as described above, while at the same time seeking to ameliorate the root causes of these determinants, namely the marginalization and systematic denial of legitimacy to slum areas.

Study aims and objectives

As has been seen in the review of the literature above, there is substantial evidence to suggest that health outcomes for a wide variety of infectious, chronic and mental illnesses are strongly affected by the urban social environment. In particular, social support and social capital, understood as the psychological and tangible support that an individual is able to draw from his or her personal social network, are seen to have a protective effect. There is little research, however, on which types of support are most meaningful in the urban context, and if this effect is uniform across both rural-urban migrants and life-long urban residents. Additionally, while residential segregation within both urban and rural areas of the United States has been shown to be associated with negative health outcomes, similar work has not been conducted in the context of low- and middle-income countries. Within these settings, insularity of a community may either hinder the establishment of ties and the utilization of services between the community and the larger city, or it may form a significant resource in terms of social capital, with community members assisting others in overcoming barriers.

The overall goal of this study is to understand the mechanisms by which migration from rural areas to a slum in Delhi may impact health, through the lens of social capital and social isolation. The specific objective of this analysis is to examine the association between migration and self-reported incidence of fever, and ways in which this relationship is modified or confounded by social capital and heterogeneity or segregation at the level of the slum.

Self-reported incidence of febrile illness, a highly common and non-specific condition, was chosen as the outcome of interest because it is assumed that the many infectious and non-infectious causes of fever are themselves impacted by a wide variety of socially-structured factors, including sanitation, nutrition, chronic stress and access to preventive medicine. Social capital in this study is conceptualized as the size of the egocentric social network of persons sharing relevant characteristics (language, religion, and place of origin) or willing and able to provide tangible support to the respondent. It is hypothesized that individuals with larger, more supportive networks would have greater access to preventive healthcare, better nutritional status, and higher SES, which would lead to more favorable health outcomes, including a lower incidence of febrile illness. Relative social isolation at the slum level is understood as the level at which a given community is able to interface with the larger city. It is expected that more diverse communities would have a larger collective network, and thus may be more able to access services within the city, while more homogeneous communities may lack this broad array of ties and thus may underutilize existing health systems leading to overall poorer health.

It is hoped that this research will provide information to policymakers to better target health promotion programs towards particularly vulnerable groups, by furthering understanding of the pathways which place these groups at additional risk. Additionally, if existing forms of social capital, and their influence on health outcomes, are better understood within the context of urban slums, future programs will be better able to mobilize indigenous resources with the aim of improving

health in urban slums, in the process increasing empowerment and ownership of these programs by the beneficiaries themselves.

Methods

Study design and context

Data analyzed for this research were collected as part of the Delhi Life of the Urban Poor (DUP)/Delhi Voters Project (DVP), during two rounds of door-to-door surveys completed February 2009 and July 2011 in over 200 slums in Delhi, India. The DVP is a randomized controlled trial implemented in 100 of the Municipal Corporation of Delhi's (MCD) 273 wards, which seeks to test the effect of local government transparency on service provision by the MCD within slum areas. Specifically, for this trial, report cards containing information on the amount and type of discretionary funding spent by councilors, and each councilors' attendance at meetings of the MCD, were published in Hindustan, the leading Hindi-language newspaper in Delhi. Sixty out of the 100 study wards were randomly selected for treatment. Newspapers containing report cards were then distributed to households within slums in treatment wards in both late 2010 and early 2012. Measured outcomes of the DVP are changes in discretionary spending and attendance patterns by councilors (collected from MCD records through 2013); electoral outcomes of the April 2012 MCD elections, depicting differences in voting patterns between treatment and control slums; and differences in voters' knowledge, preferences, and access to municipal services, as measured in an endline survey to be collected soon after the election. A baseline survey was undertaken in

February 2010 in selected slums to judge baseline knowledge and preferences of voters residing in slums.

Conceptual framework

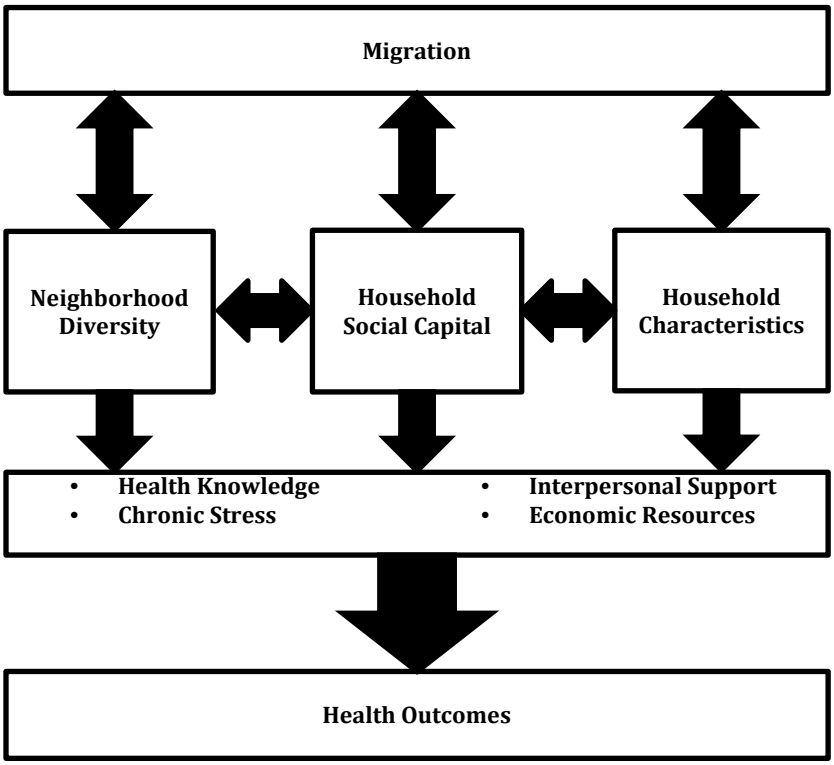
Figure 1 shows the conceptual framework used in specifying the model for this analysis. Migration is thought to be related to neighborhood diversity, household social capital and other household characteristics (which in the final model will be treated as potential confounding factors) as both a cause and an effect. For example, it may be that only households with high social capital in the rural place of origin may have the ability to migrate to urban areas, though it may be difficult to re-constitute this social capital once in an urban area. Similarly, the ethnic, linguistic or religious composition of a neighborhood may be an effect of in- or out-migration, and at the same time may contribute to further flows of migration into or out of the neighborhood. Finally, household characteristics, such as caste, socioeconomic status, education and occupation may both affect and be affected by a household's decision to migrate from a rural area to an urban one.

These three sets of distal predictors—neighborhood diversity, household social capital and other household characteristics—affect each other through a number of bi-directional mechanisms. For example, neighborhood diversity may affect household social capital through the formation of social ties between households and individuals where neighbors are highly similar or dissimilar. In the same way, an initial population of highly connected households in an area may, over time, lead to increased in-migration along ethnic, religious or linguistic lines

through multiple, overlapping ties between households in the host area and the place of origin, thus affecting neighborhood diversity. Household characteristics, as defined above, may allow a household to amass greater social capital, while the level of social capital in a household may lead to changes in these same characteristics.

The three distal predictors are in turn associated with a number of well-known proximal determinants of health, including health knowledge, chronic stress, interpersonal support and available economic resources. For example, health knowledge, including the proper and prompt in-home treatment of ailments, adequate prevention strategies and knowledge of when to seek medical advice, may be determined by available resources within the neighborhood, a household's immediate social network, and individual household characteristics such as education and socio-economic status. Other proximal determinants of health are also assumed to be affected by a combination of the three distal predictors.

Figure 1. Conceptual framework of the relationship between migration, social support, neighborhood diversity and health



This analysis seeks to quantify the association between migration status, distal predictors of health (neighborhood diversity, household social capital, and other household characteristics) and health outcomes. Further descriptions of the measurement, coding, and modeling of these constructs are described below.

Study population and sampling strategy

Both the DVP and DUP projects target slum populations, and therefore all observations collected and included in this analysis are from households living in

slums in Delhi. Due to time and budgetary constraints, it was not possible to create a sample frame of slums based on household-level criteria set out by UN-HABITAT (78). Therefore, a set of nine area-level criteria were devised to determine if a given area met the criteria for inclusion. The criteria were:

1. Presence of open sewer drains or canals
2. Presence of unpaved roads within the colony
3. High utilization of handpumps for access to water
4. Lack of private toilets within households, and high usage of public toilets
5. Presence of piles of refuse outside a designated receptacle
6. High population density, defined as most households consisting of two or fewer rooms
7. Construction of houses using unfinished brick, or collected materials
8. Household labor (cooking, cleaning) typically done outside the home
9. Presence of domestic animals other than dogs and cats (i.e., goats, buffalo, cows, chickens, etc.)

These criteria were devised through discussions with workers from the partner NGO, Satark Nagrik Sangathan (SNS), and residents of identified slum colonies. Potential sample areas were then assessed according to the criteria stated, which was then compared to a subjective assessment of whether the area was a slum or not. These measures were then compared to qualitatively judge the discriminatory power of the criteria, which was found to be adequate.

Selection of slums proceeded according the requirements of the DVP plan outlined above. Of the 273 wards of the MCD, 100 were randomly selected for inclusion within the project. All slums within each sampled ward were identified using satellite imagery and confirmed as slums by fieldwork which judged the number of the above criteria which were met in each area. Within each ward, 50 households were sampled across the enumerated slums, using a probability proportional to size approach such that larger slums within a ward were allocated more households than smaller slums. Within each slum, households were sampled geographically, with surveyors skipping a designated number of households and following the right hand rule, allowing for an approximately equal distribution of surveyed households within each slum. Surveys were conducted with the head of the household or his or her spouse if he or she was not present. A total of 5,484 surveys were conducted, and households living in areas that met a majority (at least five of the above nine) criteria were included in the present analysis, which amounted to 61.5% of the total sample (n = 3,376).

Study measures

Data included in this analysis are from the DUP dataset, which includes both observations from the DVP baseline survey as well as a second survey, collected six months later, within the same households. As the variables used in this analysis were not considered to show any strong secular trends, this analysis proceeded as the analysis of a cross-sectional survey which is representative of the larger population of people living in slums in Delhi.

In the second survey[2], the adult respondent (either the head of the household or his or her spouse) was asked to report on the *number of fevers experienced in the past year* by both him/herself and a randomly selected child (Question 1). Additionally, a *migration history* was taken, beginning with the birthplace (Question 2), and proceeding through each subsequent residence until the current residence (Questions 3-4). *Social capital measures* were collected through questions which asked who would be the first person the respondent would contact in a number of scenarios and the location of that person (Questions 5-8). *Size of the potential household network* was determined by asking the number of other households from the same place of origin as the respondent household living in either the same slum or in Delhi (Questions 9-10).

Socioeconomic status and demographic variables were collected on the first survey. Demographic variables include *language* spoken in the home (Question 11), the *religion* practiced by the respondent (Question 12), the *state of origin* of the respondent (Question 2), *occupation* of the head of the household (Question 13), and *education* of the head of the household (Question 14). Socioeconomic status was measured across several dimensions: *caste* (Question 15), *household inventory* (Question 16), *access to water and sanitation* (Question 17-18), *access to electricity* (Question 19), *ration card* held by the household (Question 20-21), and *house construction type* (Question 22-23). Household inventory included ten items: televisions, radios, bicycles, two-wheelers (motorcycles and scooters), other vehicles, mobile phones, landline phones, and refrigerators. Ration cards are

[2] Questions and valid responses are listed in Appendix 1. Question numbers corresponding to the appendix are given here in parentheses.

distributed to households by the government for the purpose of identification in the distribution of subsidized food staples including rice, flour, sugar, and cooking oil. White ration cards do not entitle the bearer to any subsidized goods, while white-stamped, yellow, and red cards entitle households to progressively more. Red ration cards are held only by households deemed below the national poverty line.

Data were cleaned and coded in Stata version 12.1, removing erroneous values and creating variables to represent the variables of interest. Two outcomes of interest were analyzed, number of incidents of febrile illness in the past year affecting the adult respondent and the number affecting a randomly selected child living in the household. Both these outcomes were coded as an event if the respondent or the child suffered more than two fevers in the past year (the median of both distributions), and as a non-event if he or she suffered two or less fevers.

The primary exposure of interest in this study is the nativity of the main respondent. Utilizing the definitions used by Iglesias et al. and others, a household was coded as migrant if the respondent (the head of the household or her/his spouse) was born outside of Delhi (103–105).

Other exposures of secondary interest were characteristics of the primary respondent's migration experience, measures of ethnic and linguistic heterogeneity within the slum and the egocentric social network of the respondent. Migration histories of the respondent were characterized using the effective number of past residences and the length of time spent living in Delhi since the most recent move into Delhi (in the case of an individual who first lived in Delhi, left, and later returned). The effective number of past residences is an adaptation of the effective

number of political parties (106). It is conceptualized as a count of residences weighted by the proportion of time spent at each previous location, such that:

$$R_{eff} = \frac{1}{\sum_{i=1}^{n} p_i^2}$$

where p_i is the proportion of the respondent's life that he or she lived in his or her i^{th} place of residence. This measure was utilized to account for individuals making brief intermediate moves between two more permanent residences.

Heterogeneity measures include the percentage of households speaking Hindi (which was the dominant language in every slum sampled), the percentage of households practicing the dominant religion of the slum, the dominant religion of the slum (coded as Hindu—which is the reference—, Muslim, or other), and the maximum percentage of households originally from the same state in the slum.

Egocentric network measures examined include support available to the household inside and outside of Delhi, the number of other households from the same place of origin living in the same slum, and the number of other households from the same place of origin living in Delhi. Social support measures asked if there is a person or group of people who would be able to provide support in three situations—by giving a loan of Rs. 5000, in providing information on job contacts, and by caring for a sick child—and, if so, whether at least one of these people lived in Delhi. Number of other households living in the slum or city was categorized as

zero (reference), one to five, six to fifteen, more than 15, and a sizable but unknown number.

Potential confounders examined in the analysis were socio-economic status (SES), occupation of the head of the household, education of the head of the household, ration card color (indicating officially-designated poverty status), religion, language spoken in the home, caste, and (in the case of the child outcome) age of the child. The SES index was constructed as a composite index of a household inventory, access to water, sanitation and electricity services, and construction materials of the house, utilizing principal components analysis. Components which together explained at least 90% of the variation were retained. Occupation was coded as unemployed, unskilled manual, skilled manual, and service, utilizing categories determined in the most recent National Classification of Occupations by the Government of India (107), with unemployed as the reference category. Education was coded as none (reference), some primary school, or some secondary school. Ration cards were coded according to official designations of white, white-stamped, yellow, red, and no ration card held, with white ration cards being the reference and indicating the least impoverished households, and red indicating the most impoverished households. Religion was coded as with the slum-level variables, as Hindu (reference), Muslim and other, while language spoken in the home was coded as Hindi or non-Hindi, with Hindi being the reference. Caste was designated as general (reference), scheduled caste, scheduled tribe, other backwards caste, and other. All caste categories, except “other”, are officially

designated by the Indian government, with non-general castes assumed to experience greater marginalization.

Analysis

Univariate descriptive analyses of all study variables listed above were undertaken and counts or means were presented for each. To test the effect of migration on health outcomes, and the differential effects of social capital on migrants and non-migrants, two multilevel mixed-effects logistic models were fitted, one each for adult and child outcomes. Models assumed correlation at the level of the slum. Initial models included fixed effects of all primary and secondary effects, all confounders, and one-way interactions between migration and each secondary effect. Initial models also included random effects of migration and a random intercept at the level of the slum. Models were evaluated independently for interaction, random effects and confounding using the hierarchical backwards elimination approach, with $p > 0.10$ from the likelihood ratio test as a criteria for exclusion of interaction terms from the model, and a 10% cutoff for determination of confounding. Odds ratios for all main and secondary exposures, and significant interactions, were reported. All analysis of models was undertaken in R version 2.14.1 using the lme4 package for the analysis of generalized linear mixed-effects models (108).

Results

A total of 2,204 complete observations were included in the final analysis of adult outcomes, while 1,712 complete observations were included in the model for child outcomes (Table 1). The reduction in sample size for the analysis of child outcomes relative to adult outcomes was due to households reporting no children under the age of 18. Of the adult outcomes used in the model, 1,532 respondents (69.5%) reported two or fewer episodes of febrile illness in the past year, while 672 (30.5%) reported more than two episodes of febrile illness in the past year. Of the child outcomes analyzed in the model, 936 (54.7%) reported the child experiencing two or fewer episodes of febrile illness in the past year, while 776 (45.3%) reported the child experiencing more than two episodes of febrile illness in the past year. Distributions of predictors and other covariates are reported in Table 1.

In both the adult and child populations, the proportion of households in which the primary respondent was born outside of Delhi was approximately 82%. Mean length of residence in Delhi, however, was relatively long at approximately 24 years in both models, while the mean effective number of residences was approximately 2.4 in both.

Economic support (ability to borrow Rs. 5000 in an emergency) was relatively more available than either employment advice or childcare. Nearly 90% of households reported the ability to borrow money in an emergency, while approximately 55% and 65% of households reported employment and childcare

support, respectively. For all three categories of support, nearly all households who reported support indicated that that support was available from a contact in Delhi.

Table 1. Distributions of predictors and covariates within adult and child datasets

	Adult		Child	
	N (%)	**Mean (S.D.)**	**N (%)**	**Mean (S.D.)**
Household-level predictors				
N	2204 (100)		1712 (100)	
More than two fevers in past year	672 (30.5)		776 (45.3)	
Migrant status				
Migrant	1801 (82.0)		1418 (82.8)	
Non-Migrant	396 (18.0)		294 (17.2)	
Effective number of residences		2.33 (0.8)		2.4 (0.9)
Number of years living in Delhi		25.0 (10.6)		24.3 (9.9)
Able to borrow Rs. 5000 in an emergency	1923 (87.3)		1505 (87.9)	
Able to borrow Rs. 5000 in an emergency and lender is in Delhi	1806 (81.9)		1407 (82.2)	
Know someone who could give job advice	1228 (55.7)		959 (56.0)	
Know someone who could give job advice and advisor is in Delhi	1175 (53.3)		918 (53.6)	
Know someone to provide emergency childcare	1426 (64.7)		1137 (66.4)	
Know someone to provide emergency childcare and caregiver is in Delhi	1411 (64.0)		1128 (65.9)	
Number of other households from place of origin living in slum				
0	551 (25.0)		418 (24.4)	
1-5	770 (35.0)		601 (35.1)	
6-15	482 (21.9)		370 (21.6)	
More than 15	400 (18.1)		323 (18.9)	
Number of other households from place of origin living in Delhi				
0	218 (9.9)		164 (9.6)	
1-5	413 (18.7)		320 (18.7)	
6-15	449 (20.4)		344 (20.1)	
More than 15	620 (28.1)		484 (28.3)	
Unknown	504 (22.9)		400 (23.4)	
Slum-level predictors				
Percent speaking Hindi in slum		83.8 (14.6)		83.8 (14.6)
Percent from dominant state of origin in slum		57.8 (16.3)		57.8 (16.3)
Percent practicing dominant religion in slum		86.3 (12.5)		86.2 (12.8)
Dominant religion in the slum				
Hindu	1971 (89.4)		1529 (89.3)	
Muslim	229 (10.4)		181 (10.6)	
Other	4 (0.8)		2 (0.1)	

	Adult		Child	
	Count (%)	**Mean (S.D.)**	**Count (%)**	**Mean (S.D.)**
Other variables				
Age of the child	--	--		8.1 (4.4)
Occupation				
Unemployed	193 (8.7)		136 (7.9)	
Manual, unskilled	1579 (71.6)		1245 (72.7)	
Manual, skilled	213 (9.7)		157 (9.2)	
Service	67 (3.0)		50 (2.9)	
Unknown	153 (6.9)		124 (7.2)	
Education				
None	1056 (47.9)		817 (47.7)	
Some primary	350 (15.9)		272 (15.9)	
Some secondary or higher	798 (36.21)		623 (36.4)	
Ration Card				
White	180 (8.2)		151 (8.8)	
White-stamped	284 (12.9)		210 (12.3)	
Yellow	528 (24.0)		399 (23.3)	
Red	409 (18.6)		297 (17.4)	
None	803 (36.4)		655 (38.3)	
Religion				
Hindu	1784 (80.9)		1380 (80.6)	
Muslim	408 (18.5)		328 (19.2)	
Other	12 (0.5)		4 (0.2)	
Language				
Hindi	1825 (82.8)		1420 (82.9)	
Non-Hindi	379 (17.2)		292 (17.1)	
Caste				
General	469 (21.3)		355 (20.7)	
Scheduled Caste	901 (40.9)		706 (41.2)	
Scheduled Tribe	186 (18.4)		141 (8.2)	
Other Backwards Caste	446 (20.2)		348 (20.3)	
Other	202 (9.2)		162 (9.5)	

The principal components analysis of household inventory, access to water, access to sanitation, house construction type and access to electricity was able to reduce the twenty-four included variables to the first fourteen principal

components, which together accounted for over 92% of the observed variation in the data.

Multicollinearity statistics indicated significant collinearity involving the interactions of migration with: percent practicing dominant religion, percent speaking dominant language, percent from dominant state of origin, ability to receive a loan from someone in Delhi, ability to obtain childcare from someone in Delhi, ability to obtain employment advice from someone in Delhi, number of households living in Delhi from the same place of origin, effective number of residences, and length of time living in Delhi. These interactions were therefore removed from the original model. Additionally, the main effect of ability to obtain childcare from someone living in Delhi was highly collinear with its corresponding non-Delhi-specific variable, and thus ability to obtain childcare from someone living in Delhi was excluded from the initial model. Variables included in multicollinearity analysis and the final model are listed in Appendix 2.

Hierarchical backwards elimination procedures led to the elimination of all interactions except the interaction between migrant status ability to obtain a loan of Rs. 5000, which was found to be significant at the $p < 0.10$ level in both models. Random effects of migrant status at the slum level were found to be non-significant in both models and were thus excluded from further analysis.

Confounding was assessed independently for both models, testing the change in the main effect of migration on fever incidence with the removal of one or more potential confounders for the model, with a standard 10% change in effect magnitude being considered the threshold for confounding. Only socio-economic

status was found to confound the relationship between migration and fever incidence in the adult model, and child age was found to be the only confounder in the child model. No precision, however, was gained through the removal of the non-confounders in the model (less than 1% reduction in the standard error), and thus all covariates were retained in the final model, the results of which are presented in Table 2.

Table 2. Results of adult and child models predicting more than two incidences of febrile illness in the past year

	Adult		Child	
	Coefficient (S.E.)	**p**	**Coefficient (S.E.)**	**p**
Household-level predictors				
Migrant	0.949 (0.431)	0.028**	0.513 (0.432)	0.235
Length of time in Delhi	-0.002 (0.005)	0.684	-0.015 (0.006)	0.018**
Effective number of residences	0.031 (0.064)	0.623	0.136 (0.069)	0.048**
Able to borrow Rs. 5000 in an emergency	1.044 (0.464)	0.025**	0.637 (0.467)	0.172
Lender is in Delhi	-0.292 (0.208)	0.159	-0.165 (0.221)	0.454
Know someone who could give job advice	0.147 (0.307)	0.631	0.234 (0.343)	0.495
Advisor is in Delhi	-0.35 (0.305)	0.252	-0.281 (0.34)	0.409
Know someone to provide emergency childcare	0.14 (0.102)	0.171	0.104 (0.111)	0.346
Number of other households from place of origin living in slum				
0 (reference)	--	0.974	--	0.234
1-5	-0.105 (0.126)		0.001 (0.136)	
6-15	-0.008 (0.143)		0.192 (0.156)	
More than 15	0.124 (0.15)		0.252 (0.164)	
Number of other households from place of origin living in Delhi				
0 (reference)	--	0.860	--	0.014**
1-5	0.022 (0.188)		0.487 (0.210)	
6-15	0.009 (0.186)		0.367 (0.207)	
More than 15	-0.190 (0.179)		0.382 (0.198)	
Unknown	0.271 (0.178)		0.530 (0.200)	
Interaction				
Migrant x Ability to borrow Rs. 5000	-1.046 (0.446)	0.019**	-0.769 (0.45)	0.088*
Slum-level predictors				
Percent speaking Hindi in slum	0.004 (0.004)	0.280	0.009 (0.004)	0.024**
Percent from dominant state of origin	-0.001 (0.003)	0.665	-0.003 (0.003)	0.372
Percent practicing dominant religion	0.005 (0.004)	0.215	-0.002 (0.005)	0.605
Dominant religion				
Hindu (reference)	--	0.973	--	0.987
Muslim	0.142 (0.189)		0.074 (0.2)	
Other	-0.098 (1.284)		-13.2 (811.2)	

***p < 0.10; **p < 0.05; ***p < 0.01**

Table 2. Continued.

	Adult		Child	
	Coefficient (S.E.)	p	Coefficient (S.E.)	p
Control variables				
Child age	--	--	-0.097 (0.012)	0.000***
SES Index (14 principal components)	--	0.103	--	0.429
Education				
None (reference)	--	0.081*		0.125
Some primary	-0.047 (0.138)		-0.156 (0.151)	
Some secondary or higher	-0.312 (0.113)		-0.188 (0.12)	
Occupation				
Unemployed/retired (reference)	--	0.089*	--	0.059*
Manual, unskilled	-0.336 (0.166)		-0.304 (0.195)	
Manual, skilled	-0.02 (0.217)		-0.232 (0.253)	
Service	-0.321 (0.317)		-0.591 (0.359)	
Unknown	-0.555 (0.245)		-0.473 (0.269)	
Ration Card				
White (reference)	--	0.304	--	0.613
White-stamped	-0.259 (0.213)		0.086 (0.227)	
Yellow	-0.334 (0.194)		0.158 (0.205)	
Red	0.053 (0.198)		0.113 (0.215)	
None	-0.171 (0.186)		0.016 (0.197)	
Religion				
Hindu (reference)	--	0.807	--	0.982
Muslim	0.032 (0.157)		0.116 (0.164)	
Other	0.145 (0.697)		-13.9 (630.4)	
Language				
Hindi (reference)	--	0.918	--	0.208
Non-Hindi	-0.015 (0.143)		-0.195 (0.155)	
Caste				
General (reference)	--	0.234	--	0.645
Scheduled caste	-0.056 (0.133)		-0.021 (0.145)	
Scheduled tribe	-0.275 (0.199)		0.01 (0.214)	
Other backwards caste	-0.165 (0.149)		0.198 (0.161)	
Other/uncategorizable	-0.090 (0.189)		0.059 (0.203)	

***p < 0.10; **p < 0.05; ***p < 0.01**

In the final adult model, significant ($p < 0.05$) predictors of reporting more than two fevers in the past year were migration, ability to borrow Rs. 5000 in an

emergency, and the interaction between the two terms. Occupation and education of the household head were weakly significant ($p < 0.10$), with all categories indicating a decrease in fever incidence relative to the reference. There were no other significant predictors of fever incidence in this model.

In the full-model predicting fevers among children, migrant status and borrowing ability were not significant, though the interaction between the two was weakly significant ($p < 0.10$). Significant ($p < 0.05$) predictors of fever incidence were length of time living in Delhi, age of the child, effective number of residences, number of households living in Delhi from the same place of origin as the sample household, and percent speaking the Hindi in the slum. Years in Delhi and age of the child were associated with decreases in fever incidence, while more households from the same place of origin, an increasing percentage of people in the slum speaking Hindi, and a greater number of effective residences were all associated with increased reports of fever. Similar to the adult model, employment of the household head was weakly significant, with all employed groups reporting a decreased incidence of fever relative to unemployed (the reference). Random intercepts (not shown) were non-significant in both models, indicating a low level of variation in the base rate of febrile illness between slums.

Table 3 presents odds ratios for main and secondary effects and interactions. Among adults, significant effects of interest were found among migrants and non-migrants, dependent on the ability to borrow Rs. 5000 in an emergency. Among those who were not able to identify someone from whom they could borrow Rs. 5000, migrants were over twice as likely (OR = 2.58, 95% CI: 1.11 – 6.01) to report

more than two episodes of fever in a year than non-migrants, while there was no significant effect of migration among those able to identify a source of an emergency loan. Among non-migrants, those able to identify a source of an emergency loan were nearly three times as likely (OR = 2.84, 95% CI: 1.14 – 7.06) to report more than two fevers in a year as those without a source of such a loan, there was no significant effect of being able to identify a source of a loan among migrants.

The odds of a child experiencing more than two fevers in the past year are decreased with each year of residence in Delhi (OR = 0.99, 95%CI: 0.97 – 1.00), respectively. An increase by one percentage point in the number of people speaking Hindi in the slum increases the odds of reporting more than two fevers in a year (OR = 1.01, 95%CI: 1.00 – 1.02). A one-unit increase in the number of effective residences also increases the odds of reporting more than two fevers among children (OR = 1.15, 95% CI: 1.001 – 1.31). Similarly, reporting any number of other households in Delhi from the same place of origin increases the odds of more than two fevers per year in children by between 44 and 70%, dependent on the number of other households present. An increase by a year in age decreases the odds of a child experiencing more than two fevers in a year (OR = 0.91, 95% CI = 0.89 – 0.93).

Table 3. Odds ratios of main effects and interactions

	Adult	Child
	OR (95% C.I.)	**OR (95% C.I.)**
Household-level predictors		
Length of time in Delhi	1.00 (0.99, 1.01)	0.99 (0.97, 1)
Effective number of residences	1.03 (0.91, 1.17)	1.15 (1, 1.31)
Know someone who could give job advice	1.16 (0.64, 2.11)	1.26 (0.65, 2.47)
Know someone to provide emergency childcare	1.15 (0.94, 1.41)	1.11 (0.89, 1.38)
Number of other households from place of origin living in slum		
0 (reference)	--	--
1-5	0.90 (0.7, 1.15)	1.00 (0.77, 1.31)
6-15	0.99 (0.75, 1.31)	1.21 (0.89, 1.65)
More than 15	1.13 (0.84, 1.52)	1.29 (0.93, 1.78)
Number of other households from place of origin living in Delhi		
0 (reference)	--	--
1-5	1.02 (0.71, 1.48)	1.63 (1.08, 2.45)
6-15	1.01 (0.7, 1.45)	1.44 (0.96, 2.17)
More than 15	0.83 (0.58, 1.18)	1.47 (1, 2.16)
Unknown	1.31 (0.92, 1.86)	1.70 (1.15, 2.52)
Interactions		
Migrant unable to borrow vs. non-migrant unable to borrow	2.58 (1.11, 6.01)	1.67 (0.72, 3.89)
Non-migrant able to borrow vs. non-migrant unable to borrow	2.84 (1.14, 7.06)	1.89 (0.76, 4.72)
Migrant able to borrow vs. migrant unable to borrow	1.00 (0.61, 1.62)	0.88 (0.25, 3.13)
Migrant able to borrow vs. non-migrant able to borrow	0.91 (0.68, 1.21)	0.77 (0.23, 2.61)
Slum-level predictors		
Percent speaking dominant language in slum	1.00 (1.00, 1.01)	1.01 (1.00, 1.02)
Percent practicing dominant religion	1.01 (1.00, 1.01)	1.00 (0.99, 1.01)
Percent from dominant state of origin	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Dominant religion		
Hindu (reference)	--	--
Muslim	1.15 (0.80, 1.67)	1.08 (0.73, 1.59)
Other	0.91 (0.07, 11.24)	N.A.
Control variable		
Child age	--	0.91 (0.89, 0.93)

Discussion

The present analysis shows that the incidence of febrile illness within both adult and child populations is associated with migration into Delhi. The determinants of febrile illness appear to be consistent in both populations, though the relative strengths of different determinants varies to some extent. Notably, different aspects of the migration experience are significant predictors of the outcome in the two populations. While nativity itself (in interaction with social capital measures) predicts febrile illness among adults, this crude measure is not predictive of illness in children. Rather, children who live in households who have moved more frequently in the past, and who have lived in Delhi for a shorter time, are at greater risk for illness.

Slum-level diversity, however, does not predict febrile illness in either population, with the exception of greater linguistic homogeneity in the slum predicting a slightly higher incidence of febrile illness among children. Social network and social capital measures had important effects in both adult and child populations. The effect of place of birth on the incidence of febrile illness varies significantly between adults who have social support and those who do not, though this effect is less strong among children. Only among children, however was the size of the network of households from the same place of origin significantly predictive of the incidence of febrile illness, with households with larger networks in Delhi reporting a higher incidence of febrile illness among their children.

Among children, the results indicate that children in households who are relatively more "rooted" in Delhi—those who move less frequently and who have resided in Delhi for a longer period—are less at risk of fever. In spite of this association, children living in households with relatively larger networks from the same place of origin living in Delhi were found to be at higher risk for experiencing more than two instances of febrile illness in the past year. Similarly, greater linguistic diversity within the slum was also found to place children at higher risk of febrile illness. Taken together, this pattern of association implies that households who are long-time Delhi residents, living in slums with a diverse population, and who have relatively little contact with individuals from their place of origin provide the healthiest environment for children.

It is not clear, however, why an increase in the number of households from the same place of origin living in Delhi would be associated with an increased risk of fever among children. Two different interpretations exist for the construct measured by the number of households from the same place of origin living in Delhi. First, that a greater number of households indicates a wider safety net in Delhi, and therefore a larger network is predictive of poorer health outcomes in children, which appears to be counter to the expected association. The second interpretation is that reporting a larger number of households from the same place of origin is indicative of a lower level of assimilation within Delhi, which is then associated with poorer health outcomes. Households with a higher level of assimilation may report fewer other households from the same place of origin either because they have less knowledge of social networks linked to the place of origin (because their Delhi-

based networks are relatively stronger), or because the lack of available contacts from the place of origin forces greater assimilation within Delhi itself. With the data available in the dataset, it is not possible to distinguish between these potential mechanisms.

Within the child model, it seems clear that social capital and processes of assimilation are tied to health outcomes. Rates of movement between residences, measured both by the length of time resident in Delhi and the weighted count of past residences, may impact child health in a number of ways. A greater rate of movement may decrease income, decrease a household's food security, and decrease a household's ability to access healthcare. Results from this analysis are consistent with other studies showing linking poor health outcomes to decreased nutrition status, healthcare utilization and income opportunities among migrants, both in India and abroad (21,77,109,110). In the present analysis, however, migration status of the household itself (as indicated by the place of birth of the head of the household) does not independently predict a higher incidence of febrile illness—these outcomes are predicted by greater rates of mobility rather than migrant status *per se*.

Among adults, migrant status was found to interact with the ability to secure a personal loan to predict incidence of febrile illness. It is assumed that the ability to raise a loan of Rs. 5000 in an emergency is a proxy measure for ability to mobilize social and economic resources. Therefore, among those who report being unable to mobilize those resources, migrant status is a significant predictor of greater fever incidence, but not among those who are able to mobilize these resources.

Conversely, among non-migrants, those who were able to receive a loan were more likely to report more than two instances of febrile illness in the past year than those unable to raise a loan, but there was no significant effect of being able to receive a loan among migrants.

An interpretation of the first effect is that, while migrant status may have a negative effect among those lacking an informal safety net in the receiving area, this disadvantage is completely mitigated by the safety net. The second finding, that non-migrants are likely to report more cases of febrile illness when reporting this safety net, but there is no effect of social support on febrile illness among migrants, is much more puzzling and is in the opposite direction as would be expected if such a safety net were assumed to have a protective effect. This relationship may be a result of those who are in worse health having had to call on such resources in the past, and thus being more able to specify who they would contact in the future under similar circumstances.

In comparing the two models, effects across most predictors are similar in direction, but differ substantially in magnitude and significance, indicating that the processes which shape health outcomes are similar in both adults and children, but the relative importance of factors in these processes may differ. In particular, mobility (measured as both effective number of residences and length of time in Delhi), migrant status, available informal financial support, and the interaction between migrant status and available informal financial support, are similar in size and direction, if not precision, in both models.

As a measure of social capital, the question "Who would you go to for an emergency loan of Rs. 5000?" captures a very specific dimension of the concept: having economic assistance in the face of negative external shocks. Similar questions related to employment advice and childcare in case of an emergency attempt to capture additional dimensions of the same concept. From the results, it is clear that ability to garner financial assistance is more predictive of health outcomes among both adults and children than ability to access either employment advice or childcare. The reason that this might be true, and why this seeming increase in social capital would be predictive of poorer health in non-migrant populations as discussed above, is not clear from the data available and merits further research.

Both models also predict migration into Delhi to have significantly deleterious health effects. Notably, though, in the adult model negative health outcomes are related specifically to being born outside Delhi (and only among those without the ability to muster financial assistance), while in the child model, negative health outcomes are associated with increased mobility within the household. In the adult case, it can be interpreted that these outcomes may be due to increased acculturative stress, in addition to exposures which may be specific to the migrant experience. This explanation is in line with other work that has found acculturative stress is predictive of poor physical and mental health outcomes (14,72). In the child model, where it is assumed that most children were themselves born in Delhi, migrant status of the head of the household was not predictive of poor health when controlling for other factors. Here, poorer health was related most directly to

increased mobility of the household, which may be indicative of the special risks which are incurred during frequent moves, including those mentioned above.

Strengths of this study include the sampling method employed and the detail available on each observation. By selecting a large number of slums (n = 142) which were widely distributed across Delhi, this dataset may be more representative of the slum population of Delhi than would be possible from a more intensive survey of a few selected slums. The questionnaires themselves also provide a great deal of detail on respondents. In particular, the full migration history and detailed information on help available and utilized within social networks provides a wealth of detail and nuance on migration trajectories and social capital of households living in slums in Delhi, which has not previously been available on such a large scale.

There are at least three limitations for this study, which are related to the available model variables and the modeling strategy employed. First, the child model relative to the adult model includes an additional parameter, age. Information on respondent age was unfortunately not reliably collected among adults, and thus it was impossible to include this in the adult model. Given that this parameter exerted such a strong effect within the child model, it is possible that there may be unmeasured confounding in the adult model due to its omission. Similarly, both models do not include gender which was not available in the DUP dataset, but has been seen to significantly affect health outcomes in both adult and child populations (94,111–113), and thus may be a source of further confounding.

Second, the original outcome variable, the number of instances of febrile illness experienced by an individual in the past year, was naturally distributed as an

overdispersed Poisson random variable, with the variance being approximately five times larger than the mean for both adults and children. This distribution, most appropriately described within a negative binomial model, was impossible to model within a mixed-effects framework in the available software, and thus the outcome was re-coded as a binary variable, with the median value serving as the cut-point. In doing so, a large amount of variation in outcomes was lost, and it was no longer possible to estimate the rate ratio for individual predictors. Further work should be undertaken to more appropriately model the relationship between the naturally-coded outcome (count of fevers in the past year) and predictors, either within a marginal negative binomial model or using recently developed alternative approaches to estimate a mixed-effects model within a Poisson distribution, with corrections made for the observed overdispersion (114,115).

Finally, it was also found to be unfeasible to entirely account for differential selection probabilities between study sites. While attempts were made in sampling to ensure relatively equal selection probabilities at each site, due to the large variation in slum size, it is known that selection probabilities varied to a non-negligible degree. To account for this, the initial modeling strategy included the use of probability weighting. Software limitations again precluded the use of these weights within a mixed effects model, and as such, the results presented in the current analysis are not generalizable beyond the sampled population.

While the findings of this study must be viewed within the context of the above limitations, there are a number of important public health implications raised here. First, this study echoes the findings that rural-urban migration, and increased

population mobility as a whole, has important health effects, and may place migrant populations at special risk for adverse health outcomes (44,60,65,70,77,110). It is important to note, however, that various aspects of the migrant experience may differentially affect child and adult populations. While adults may benefit more greatly from programs which seek to mitigate acculturative stress, it seems that greater gains in child health may be achieved through programs which mitigate shocks associated with frequent moves.

Second, these findings suggest that greater social capital may decrease the risk of illness, especially among adult migrants. In this case, formal and informal organizations which encourage either greater connections between migrants of similar backgrounds (69), or build social capital among residents of slums through residents' and self-help associations (116,117), may have important health benefits, and thus should be supported by government and non-governmental organizations seeking to promote urban health.

These findings may be furthered strengthened through additional qualitative and quantitative work. Qualitative studies which seek to elucidate possible pathways by which migrants to cities access basic services and adapt to urban life, and potential barriers and stress points within these pathways, would allow for a more focused investigation into causal determinants of migrants' health. Qualitative interviews could also further understand the social meaning of interpersonal loans, and identify other potentially salient types of social capital with regards to the health of migrant populations. Additional quantitative research into the causal pathways of migrant health should attempt to further investigate which types of

social capital are most significantly associated with health outcomes. This research must be careful to select a representative survey population, and seek to incorporate repeated measures, in order to further understand what temporally-specific health effects of migration might exist, and whether these effects are mitigated with increased adaptation within the receiving location.

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Appendix 1: Survey questions

1. "How many times in the past year have you/the child experienced a fever?"
    a. Valid response was numeric
2. "Where were you born?"
    a. Valid response was name of state in India or foreign country
3. "How long did you live in that house?"
    a. Valid response was numeric
4. "Where did you move after that?"
    a. Valid response was name of state and village/town/city
5. "Who would you go to first if you needed Rs. 5000 in an emergency?"
    a. Valid response was anyone from a list of 55 categories of individuals, including relatives, employers, neighbors, and various officials and institutions likely to exist within the immediate vicinity
6. "Who would you go to first if you needed help getting a job for yourself or someone else?"
    a. Valid responses were the same as question 5
7. "Who would you go to if you needed to leave your children or a sick relative for one day?"
    a. Valid responses were the same as question 5
8. "Where does this person live?"
    a. Place of origin (rural)
    b. Place of origin (urban)

c. Other rural area

d. Other (not Delhi) urban area

e. Delhi – in this *basti* [slum]

f. Delhi – not in this *basti*

g. Other

9. "Approximately how many other household in this *basti* are from your place of origin?"

    a. Valid responses were numeric

10. "Outside of this *basti*, approximately how many other households do you personally know in Delhi who are from your place of origin?"

    a. Valid responses were either numeric or "Some are known, but not exact number"

11. "What language do you speak in your home?"

    a. Hindi

    b. Urdu

    c. Punjabi

    d. Magadhi

    e. Bengali

    f. Marwari

    g. Bhojpuri

    h. Maithili

    i. English

    j. other

12. “What is your religion?”
    a. Hindu
    b. Muslim
    c. Sikh
    d. Jain
    e. Buddhist
    f. Christian
    g. Other
13. “What is the occupation of [name of head of the household]?”
    a. Valid responses were 45 common occupations derived from the National Classification of Occupations (107), which were field-tested for relevance to the sampled population
14. “What is the highest level of occupation of [name of head of the household]?”
    a. Levels were coded as none, the standard (grade) completed, or some bachelors, completed bachelors, some post-bachelors, completed post-bachelors.
15. “Are you a member of a scheduled caste (SC), a scheduled tribe (ST), or an other backwards caste (OBC)?”
    a. None-General Caste
    b. Yes-SC
    c. Yes-ST
    d. Yes-OBC
    e. other/unknown.

16. “How many [items] are owned by your household?”
    a. Valid answers were numeric
17. Access to water was determined through a checklist of whether or not the household had access to any of the following:
    a. Private piped indoor water connection from municipal supply;
    b. Private piped outdoor water connection from municipal supply;
    c. Shared piped outdoor water connection from municipal supply;
    d. Shared outdoor handpump from municipal supply;
    e. Private indoor water connection from well;
    f. Private outdoor handpump from well;
    g. Private outdoor piped connection from well;
    h. Shared outdoor piped connection from well;
    i. Water distributed by tanker trucks.
18. Access to sanitation was determined through a checklist of whether or not the household had access to any of the following, and if so, if it flushed to a piped sewer, an open sewer, emptied into an improved pit, or emptied into an unimproved pit:
    a. Private toilet inside the home
    b. Private toilet outside the home
    c. Private toilet shared by neighboring households
    d. Public (government- or NGO-maintained) toilets
    e. Open land commonly used for defecation
19. “Do you have an electricity connection in your home?”

a. Yes

b. No

20. “How many ration cards are owned by members of your household (including yourself)?”

    a. Valid answers were numeric

21. “What color are these ration cards?”

    a. White

    b. White-stamped

    c. Yellow

    d. Red

22. “How are the walls of this dwelling constructed?”

    a. Concrete/slab

    b. Wood and/or corrugated metal

    c. Collected materials

    d. Tent/tarp/palm leaves

23. “How is the roof of this dwelling constructed?”

    a. Concrete/slab

    b. Wood and/or corrugated metal

    c. Collected materials

    d. Tent/tarp/palm leaves

Appendix 2: Model Variables

Included in collinearity diagnostics	Included in initial model
Household-level predictors	
Migrant	Migrant
Effective number of residences	Effective number of residences
Length of time in Delhi	Length of time in Delhi
Able to borrow Rs. 5000 in an emergency	Able to borrow Rs. 5000 in an emergency
Able to borrow Rs. 5000 in an emergency and lender is in Delhi	Able to borrow Rs. 5000 in an emergency and lender is in Delhi
Know someone who could give job advice	Know someone who could give job advice
Know someone who could give job advice and advisor is in Delhi	Know someone who could give job advice and advisor is in Delhi
Know someone to provide emergency childcare	Know someone to provide emergency childcare
Know someone to provide emergency childcare and caregiver is in Delhi	--
Number of other households from place of origin living in slum	Number of other households from place of origin living in slum
Number of other households from place of origin living in Delhi	Number of other households from place of origin living in Delhi

Included in collinearity diagnostics	Included in initial model
Slum-level predictors	
Percent speaking Hindi	Percent speaking Hindi
Percent practicing dominant religion	Percent practicing dominant religion
Percent from dominant state of origin	Percent from dominant state of origin
Dominant religion in the slum	Dominant religion in the slum
Other variables	
Child age (child model only)	Child age (child model only)
SES Index	SES Index
Education of head of household	Education of head of household
Occupation of head of household	Occupation of head of household
Ration Card	Ration Card
Religion	Religion
Non-Hindi language spoken in home	Non-Hindi language spoken in home
Caste	Caste

Included in collinearity diagnostics	Included in initial model
Interactions	
Migrant x Effective number of residences	--
Migrant x Length of time in Delhi	--
Migrant x Percent speaking Hindi	--
Migrant x Dominant religion in the slum	Migrant x Dominant religion in the slum
Migrant x Percent practicing dominant religion	--
Migrant x Percent from dominant state of origin	--
Migrant x Able to borrow Rs. 5000 in an emergency	Migrant x Able to borrow Rs. 5000 in an emergency
Migrant x Able to borrow Rs. 5000 in an emergency and lender is in Delhi	--
Migrant x Know someone who could give job advice	Migrant x Know someone who could give job advice
Migrant x Know someone who could give job advice and advisor is in Delhi	--
Migrant x Know someone to provide emergency childcare	Migrant x Know someone to provide emergency childcare

Included in collinearity diagnostics	Included in initial model
Interactions	
Migrant x Know someone to provide emergency childcare and caregiver is in Delhi	--
Migrant x Number of other households from place of origin living in slum	Migrant x Number of other households from place of origin living in slum
Migrant x Number of other households from place of origin living in Delhi	--