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Understanding the Climate Change-Migration Nexus through the Lens of Household Surveys

An Empirical Review to Assess Data Gaps

Marco Letta
Pierluigi Montalbano
Adriana Paolantonio

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Abstract

Over the past two decades, the causal relationship between climate change and migration has gained increasing prominence on the international political agenda. Despite recent advances in both conceptual frameworks and applied techniques, the empirical evidence does not provide clear-cut conclusions, mainly due to the intrinsic complexity of the phenomena of interest, the irreducible heterogeneity of the transmission mechanisms, some common misconceptions, and, in particular, the paucity of adequate data. This data-oriented review first summarizes the findings of the most recent empirical literature and identifies the main insights as well as the most important mediating channels and contextual factors. Then, it discusses open issues and assesses the main data gaps that currently prevent more robust quantifications. Finally, the paper highlights opportunities for exploring these research questions, exploiting the potential of the existing multi-topic and multi-purpose household survey data sets, such as those produced by the World Bank's Living Standards Measurement Study. The paper focuses on the Living Standards Measurement Study–Integrated Surveys on Agriculture program to discuss potential improvements for integrating standard household surveys with additional modules and data sources.

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Understanding the Climate Change-Migration Nexus through the Lens of Household Surveys: An Empirical Review to Assess Data Gaps[*]

Marco Letta
Sapienza University of Rome and Global Labor Organization (GLO)
marco.letta@uniroma1.it

Pierluigi Montalbano[1]
Sapienza University of Rome and University of Sussex
pierluigi.montalbano@uniroma1.it

Adriana Paolantonio
Development Data Group, The World Bank
apaolantonio@worldbank.org

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[1] *Corresponding author*. E-mail: pierluigi.montalbano@uniroma1.it

1. Introduction

In the last couple of decades, the causal relationship between climate change and migration has emerged as a central issue for both scholars and policy makers, receiving growing attention in the media and public debate and gaining an important place among the policy priorities of the global agenda. Environment and climate change have been formally recognized as key drivers of migration in the UN Global Compact for Safe, Orderly and Regular Migration (GCM) endorsed by the UN General Assembly in 2018. The Sustainable Development Goals (SDGs) explicitly include a specific target (10.7) to "facilitate orderly, safe, and responsible migration and mobility of people, including through implementation of planned and well-managed migration policies". As a consequence of this increased prominence at the international level, climate-induced human migration has become one of the main channels of interest for the quantification of the socioeconomic impacts of future climate change. The common expectation is that an increase in average global temperature of 2°C or more above pre-industrial levels would result in substantially higher migration flows in the coming decades (Myers, 2002; Biermann and Boas, 2010), a view which is endorsed by the recent Groundswell reports from the World Bank (Rigaud et al., 2018; Clement et al., 2021).

Concerns about potentially dramatic increases in migratory flows triggered by large-scale climate-induced environmental phenomena have spurred the birth of an empirical research field dedicated to shedding light on the human mobility consequences of climate-related hazards. As a result, a growing body of research has started to investigate the causal link between the two phenomena to satisfy the need for reliable projections and provide robust empirical evidence on the issue. While common wisdom assumes that climate change will progressively become one of the main push factors shaping migratory flows in the coming decades, experts warn that a direct link between environmental factors and migration is not easy to identify, and the empirical evidence does not provide clear-cut conclusions. The empirical results differ depending on the environmental factors considered, the data and scale of the analysis, the methodology employed, and the geographical contexts covered. Even within the same studies, estimates of the size and direction of climate-related migration differ substantially (Hoffmann et al., 2020).

In this respect, lack of data has been the most severe constraint for a long time. Notwithstanding the increasing availability of panel micro data sets, coupled with refinements of conceptual frameworks and advances in econometric techniques, there are still many key questions to tackle and technical hurdles to overcome: given the need to differentiate across types of migration (displacements, rural-urban flows,

international migrations), what are the information needs? And how to prioritize? What are the opportunities offered by the household survey data collection? What would it be possible to achieve with slight modifications to the current data collection instruments utilized by popular, long-established household survey programs, such as the World Bank's Living Standards Measurement Study (LSMS)?

This critical review aims to shed light on the issues above. Given the vastness of the topic and the huge body of work in the field, a few preliminary clarifications on the scope of this review are in order: first, this review has an explicit orientation toward the *empirical* and *data* perspective on the climate change-migration links. Hence, we look at retrospective studies using historical data, we assume as given the state of the art of the theoretical underpinnings of the current empirical investigation, and we do not consider studies on projections or predictions of future migratory flows; second, since it is now widely recognized that developing countries, which are both hotter and poorer, will be disproportionately affected by climate change (Auffhammer, 2018; Dell, Jones and Olken, 2014; Nordhaus and Moffat, 2017; Tol, 2018), the focus of this work will be on migration originating within and/or from these countries; third, we will focus on the more *recent* empirical advances. This means we limit our exploration to studies and works published in the last decade (specifically, from 2010 on);[2] fourth, in our assessment of data gaps in household survey data, we will look specifically at the Living Standards Measurement Study (LSMS) collection by the World Bank. The LSMS has been the World Bank's flagship household survey program since 1980, and it is currently a global leader in the methodological development of rich and extensive multi-topic questionnaires designed to study various aspects of household welfare. Within the broader LSMS program, we restrict our attention to the LSMS-ISA household survey program, the explicit aim of which is to improve the availability, quality, and relevance of agricultural data in multi-topic, multi-purpose household surveys (Carletto and Gourlay, 2019). The reason is that the LSMS-ISA has a distinct advantage with respect to standard LSMS surveys when it comes to studying issues specifically related to climate change, as its strong focus on agriculture allows one to study the impacts of weather- and climate-related events on several household welfare outcomes, that might either trigger or prevent migratory flows, as well as exploring farmers' adaptation responses, especially *in situ* ones, that complement migration as coping strategies in the face of climatic shocks. Nonetheless, most of the reflections and recommendations we propose throughout this paper are also relevant to LSMS surveys more broadly and to multi-topic and multi-purpose household surveys in general.

[2] For reference to the literature before 2010 see Piguet et al. (2011).

This work is organized as follows. Section 2 reviews the most recent empirical literature on the causal relationship between climate change and migration. This section also clarifies important conceptual distinctions, summarizes the key open research questions, and takes a closer look at Sub-Saharan Africa, the area where the LSMS-ISA survey program currently operates. Section 3 presents the empirical and methodological challenges and highlights the related data gaps. Section 4 takes a closer look at the LSMS-ISA data collection and discusses its main limitations and possible use for empirical work. Section 5 suggests potential improvements and add-on modules to be integrated into future LSMS-ISA surveys. Section 6 sets up an agenda for future work and concludes.

2. Review and current state of the literature

2.1 A synthesis of recent empirical findings

In this subsection, we carry out an updated review of the literature by focusing on the period 2010-2022.[3] Overall, even the most recent literature still provides mixed and inconclusive evidence about not just the magnitude, but even the sign of the climate-migration relationship. Heterogeneity, depending on several context-specific features including, *inter alia*, the type and frequency of climatic shocks, peoples' resources and adaptation strategies, seems to be an irreducible aspect of this delicate matter, that rules out blanket generalizations on the nexus between climate change and (im)mobility. Such complexity calls for caution in issuing predictions that climate change will force tens of millions of people to move within and/or out of their own country (Rigaud et al., 2018; Clement et al., 2021) and to pay more attention to the potential of climate change in preventing voluntary migration and trapping more vulnerable and poorer populations in immobility.

By analyzing this flourishing strand of the literature, we flesh out some thematic issues that we see as pivotal for the subsequent analysis of the empirical issues and data gaps. Specifically, we look at recent insights into five key facets of the climate–migration relationship as they have emerged in the literature: slow- vs fast-onset events (United Nations Framework Convention on Climate Change, 2012; Bohra-Mishra, Oppenheimer, and Hsiang, 2014); direct and indirect links (Bardsley and Hugo, 2010); internal

[3] Our survey is a data-oriented synthesis of selected recent findings relevant for the study of the potential of household survey data. For general and more comprehensive reviews and meta-analyses of the literature on the climate-migration relationship, we recommend readers to consult Cattaneo et al. (2019), Kaczan and Orgill-Meyer (2020), and Hoffmann et al. (2020).

vs international migrants; liquidity constraints; and migration as adaptation.[4]

A. Fast-onset events versus slow-onset changes

The migration impacts of fast-onset extreme weather events (such as hurricanes, heavy rains, floods, and landslides) related to climate change are usually sudden and direct, resulting mainly in temporary movements over short distances (McLeman and Gemenne, 2018). A specific strand of the literature investigated the role of floods on migration, with mixed results: while Gray and Mueller (2012a) and Bohra-Mishra, Oppenheimer, and Hsiang (2014) document a lack of significant effects of floods on migration in, respectively, Ethiopia and the Philippines, Mueller et al. (2014) find that floods reduce the probability of migrating in Pakistan. Koubi et al. (2016) show that in Vietnam fast-onset shocks are more likely to trigger migration, whereas long-term environmental changes (such as salinization) *reduce* the likelihood of migration. Robalino, Jimenez, and Chacón (2015) provide evidence that flooding and other hydro-environmental emergencies increase migratory flows in Costa Rica, but also find that more severe emergencies decrease migration. Kaczan and Orgill-Meyer (2020) argue that this may happen as floods and other fast-onset shocks rapidly deplete household assets and resources, leaving households unable to migrate. Using a global data set which combines climatic, census, and night-light data, Castells-Quintana, McDermot and Krause (2021) study the relationship between changes in weather patterns and the spatial distribution of population and economic activity, and find that worse climatic conditions are associated with higher urbanization. Their results suggest that while slow-onset changes in climate may lead to more permanent, and more long-distance, movements, sudden-onset events are primarily associated with temporary displacements and short-term migration to nearby urban areas. Koubi et al. (2022) use survey data from Cambodia, Nicaragua, Peru, Uganda, and Vietnam and document that less educated and lower-income people are less likely to migrate after exposure to fast-onset shocks, compared to people endowed with higher education and more economic resources. Finally, even in the absence of sudden resource depletion, in poor countries the populations affected may not have enough monetary resources for long-distance migration (Zickgraf and Perrin, 2016). Cattaneo et al. (2019) emphasize that the main current insight of this strand of the literature is that the potential for fast-onset events to cause long-term, long-distance migrations appears limited, especially in the case of costlier international migration.

In contrast, slow-onset changes are more likely to induce migration than rapid-onset ones, but the

[4] These five thematic subsections have been selected among many topics, due to their relevance and prominence for the assessment of data gaps we conduct.

literature has paid less attention to the migration outcomes of slow-onset changes compared to sudden disasters (Kaczan and Orgill-Meyer, 2020). Part of the reason is that slow-onset changes are not regarded as sufficiently extreme to trigger migration, since they have less of an immediate impact on people (Koubi et al., 2022). The effect of events such as drought, desertification, and warming on migration is less sudden than floods, landslides, hurricanes and similar, because they tend to emerge gradually, and attribution is intrinsically more difficult for departures in response to gradual changes. Moreover, migratory flows can be staggered, more difficult to capture and more susceptible to measurement error.
There is a body of works documenting that slow-onset changes and rising temperatures increase migration (Bohra-Mishra et al., 2017; Cai et al., 2016; Dallmann and Millock, 2017; Dillon, Mueller, and Salau, 2011; Feng, Krueger, and Oppenheimer, 2010; Gray and Mueller, 2012a, 2012b; Hunter, Murray, and Riosmena 2013; Jessoe, Manning, and Taylor 2018; Mastrorillo et al. 2016; Mueller et al., 2014). Many of these studies are discussed in other sections of the paper. However, there are also some notable exceptions in this literature showing that slow-onset changes may also have the opposite effect, resulting in a reduction in migration. For example, Cattaneo and Peri (2016) find that, consistent with the presence of severe liquidity constraints, higher temperatures reduce the probability of migration from poor countries. The results of Cottier and Salehyan (2021) and Martinez Flores, Milusheva and Reichert (2021) on the role of droughts in influencing international migration support this conclusion. From a within-country perspective, Hirvonen (2016) shows that temperature anomalies decrease (male) migration in rural Tanzania because of tightened liquidity constraints. Liu et al. (2022) study responses to slow-onset temperature changes in Indian districts, and conclude that progressive warming and rising temperatures inhibit structural transformation and limit rural-urban migration for households living in isolated areas. Other authors emphasize that, in most cases. migration depends much more on political and economic factors and is only minimally associated with slow-onset changes. For example, Selby et al. (2017) find that environmental variables have a marginal role in explaining migration flows to the Syrian Arab Republic in the period before the outbreak of the civil war. Similarly, Niva et al. (2021) performed a geospatial analysis of a gridded global net migration data set for the decade 1990-2000, and found that slow-onset changes, such as droughts and water scarcity, were the dominant environmental events in explaining net-migration. Yet, they also emphasize that income levels and adaptive capacity crucially mediate environmental variables in determining migration outcomes.

In short, while there seems to be a prevailing consensus that slow-onset shocks do increase migratory flows, there are cases in which the opposite happens, and affected populations are instead trapped in

immobility because of the negative consequences of such shocks on their liquidity. This should come as no surprise: since the determinants of migration, and especially climate-related migration, are complex (IPCC, 2014), it is expected that the sign of the relationship cannot be known *a priori*, as the direction will depend on local circumstances and is ultimately an empirical question.

B. Direct versus indirect effects

Climate change could exert both direct and indirect effects on migration. In the latter case, one must understand how climatic events affect other drivers of migration, via demographic, socio-economic and political channels. Among the main channels of the indirect effects of weather- and climate-related hazards on migration, the two most important ones are the economic and socio-political drivers. To date, however, there is only limited and partial evidence about these links. Feng, Krueger, and Oppenheimer (2010) provide empirical support about the links between extreme temperatures, crop yields, farmers' income, and migration from Mexico to the United States. In an important study, Marchiori, Maystadt, and Schumacher (2012) leverage annual panel data from 1960-2010 and find that in Sub-Saharan Africa weather shocks boost rural-urban migration through a decrease in rural wages. In turn, this weather-driven internal migration into cities brings about downward pressure on urban wages, causing urban workers to move internationally, a mechanism they label the 'economic geography channel'. Similarly, Dallmann and Millock (2017) find that drought effects on inter-state migration in India are stronger in agricultural states. On top of these microeconomic, household-specific income channels, there is also a macro-level income driver: developing countries are particularly vulnerable to climate-related hazards, because they have a large share of their income in agriculture (the most weather-dependent sector), tend to be hotter and closer to biophysical limits, and lack adaptive capacity to cope with the negative impacts of climate change. For example, using bilateral migration data from 1980 to 2010, Cai et al. (2016) demonstrate that temperature shocks induce international migration only from agriculture-dependent countries and increase migration to OECD countries. Investigating the role of climatic factors in engendering international migration, Beine and Parsons (2015) find evidence of an indirect channel operating through wages. Niva et al. (2021) find that income is a key determinant in explaining both net-negative and net-positive migration, and conclude that it is the difference between income-levels of the origin and destination areas that matters, rather than income level *per s*e. Other than affluence, the main socio-political factor investigated in the specialized literature is the well-known (and often prominent in the media) conflict channel. For example, Kelley et al. (2015) suggest that a prolonged and unprecedented drought in parts of Syria exacerbated the (pre-existing) vulnerability of the affected population,

prompting them to migrate. According to their view, migration, in turn, increased tensions and contributed to the outbreak of the civil war. Note, however, that there are sharp disagreements about this possible causal role in the Syrian civil war played by climate change via migration (Fröhlich, 2016; Selby et al., 2017) and that, more generally, the relationship between migration, climate change, and conflict is particularly complex and context-specific.

C. International versus internal migration

Previous research paid more attention to weather- and climate-related international migration due to the paucity of internal migration data in developing contexts (Laczko and Aghazarm, 2009). However, the picture has changed in the last decade, as we are witnessing an increasing number of studies focusing on the relationship between weather shocks and short- or long-distance within-country movements, sometimes even comparing migration outcomes across multiple types of destinations. Gray and Mueller (2012b) study the effects of natural disasters in Bangladesh and find that these are stronger and more significant for local movements than long-distance outmigration. Jessoe, Manning, and Taylor (2018) show that extreme heat events in Mexico boost rural-urban internal migration as well as cross-border migration to the United States. Hirvonen (2016) finds that, in rural Tanzania, temperature increases reduce internal migration via increased liquidity constraints implied from the estimated negative consumption shock, but detects this effect only for men. Peri and Sasahara (2019), using a gridded global data set covering the period 1970-2000, find that progressive warming reduces rural-urban migration in poorer countries but increases it in middle-income countries. Gray and Bilsborrow (2013) find that adverse rainfall conditions reduce local, short-distance migration (i.e., moves within the same canton[5]) and international migration in Ecuador, but increase internal long-distance (between-canton) migration, pointing to highly heterogeneous impacts concerning the type of migration. Nawrotzki, Riosmena, and Hunter (2013) find a positive and statistically significant relationship between weather anomalies and international migration from Mexico to the United States. Liu et al.'s (2022) work on India also shows that increasing temperature can reduce internal rural-urban migration. Cottier and Salehyan (2021) employ temporally disaggregated data on the detection of unauthorized migrants at the EU's external borders and report that droughts in origin countries do not increase international migration towards the European Union but, if anything, they reduce it, in particular for countries dependent on agriculture, whereas more rainfall increases migration. Their interpretation of the results is that international

[5] Cantons are the second-level subdivisions of Ecuador, below the provinces.

migration is cost-prohibitive and that adverse weather shocks amplify liquidity constraints. Similarly, the study by Schutte et al. (2021) on the association between climatic conditions and asylum migration reveals that temperature anomalies are weak predictors of bilateral asylum migration to the European Union, and concludes that future asylum migration will mainly be driven by political changes rather than by climate change. This is in line with the findings of Martinez Flores, Milusheva and Reichert (2021) for West and Central Africa, who estimate that a standard deviation decrease in soil moisture leads to a 25-percent reduction in the number of international migrants, likely due to liquidity constraints. Bekaert, Ruyssen and Salomone (2021) leverage individual-level data from Gallup World Polls conducted in 90 countries to show that exposure to environmental stressors increases the probability of intending to migrate both domestically and internationally (but more so intra-regionally), especially in rural and less developed regions.

In short, there seems to be wide heterogeneity in the type and destination of migratory flows triggered by climatic shocks, depending on a variety of factors including, among others, the severity and frequency of the shock, the gender and resources of the affected individuals, and the context of the case study. Despite such heterogeneity, however, meta-analyses of the existing studies have found evidence that the case for weather-related migration is much more compelling for internal, within-country movements than for international cross-border flows (Hoffmann et al., 2020), a finding which contradicts the 'conventional wisdom' about large-scale international migration triggered by climate change. Lastly, an important missing piece, indeed also due to data gaps, is the paucity of studies reconstructing a potential 'climate migration chain' that might be triggered, directly or indirectly, by climatic changes in the original affected areas. It is not implausible to imagine a scenario in which a future increase in the frequency or intensity of weather shocks in a rural developing context will determine rural-urban internal migration which, in turn, gives rise to international, cross-border movements of urban workers due to changes in local labor markets. Marchiori, Maystadt and Schumacher (2012) show that a similar 'economic geography' mechanism had already taken place in Sub-Saharan African countries in past decades. If and how much this kind of climate migration chain will become more relevant as climate change intensifies, for the moment remains speculation.

D. Heterogeneous strategies and the role of liquidity constraints

A crucial insight from the most recent literature is that climate-related hazards can cause or worsen liquidity constraints (Bryan, Chowdhury, and Mobarak, 2014; Cattaneo and Peri, 2016; Cottier and

Salehyan, 2021; Hirvonen, 2016). It is precisely for this reason that the capacity for migration in response to climatic shocks is much more limited than commonly assumed: poor people, who are disproportionately affected by climate change, have more incentives to migrate but often cannot leave because they lack the necessary resources (Cattaneo et al., 2019). In this perspective, migration is a costly investment in risk diversification that only richer households can undertake, while poorer households are "forced to stay" rather than "forced to move" (Kaczan and Orgill-Meyer, 2020). Depending on the interaction between the severity of the climatic event and household-specific characteristics such as wealth, number of income sources, assets and resources, we should expect a wide heterogeneity of outcomes depending on whether liquidity constraints or migratory responses ultimately prevail. Indeed, the empirical evidence is mixed, with some studies showing that the poorest households are more prone to migrate in response to weather shocks (Gray and Mueller, 2012b; Mueller, Gray, and Kosec, 2014; Mastrorillo et al., 2016), while others find that liquidity constraints trap poor people in immobility (Cattaneo and Peri, 2016; Hirvonen, 2016; Bazzi, 2017). Cattaneo et al. (2019) argue that this contradictory evidence can be explained by the different types of migration involved: poor families respond to negative shocks through low-return or even "survival" migration, taking the form of temporary movements across short distances, whereas wealthier families engage in risk management migration, which is typically costlier, semi-permanent and longer-distance migration. Koubi et al. (2022) suggest that (im)mobility depends on both the type of the climate shock that individuals experience and their adaptive capacity in terms of endowments and resources. The simulations by Choquette-Levy et al. (2021), who parameterize an agent-based model on household survey data from Nepal, support this perspective, but also highlight that cash transfers and risk transfer mechanisms may prevent climate-induced immobility of farmers.

In short, the final outcome is ultimately household- and context-specific. In such a complex picture, migration and immobility are only two of the possible outcomes, and the decision to leave can be interpreted as one of many potential adaptation strategies that an individual or household can adopt. As such, there is a need to improve our understanding of the causes and consequences of the immobility of populations 'trapped' by environmental disasters, because too often the policy focus is on 'those who leave' rather than to 'those who cannot' (Findlay, 2012).

E. Migration as adaptation

One of the most interesting advances in the scientific literature is the progressive integration of the issues

of migration and adaptation into a single, unified conceptual framework. In such a framework, the decision to migrate constitutes *one* of the possible strategies for adapting to climate change. There is some empirical support for the notion that migration is a subset of decision options within the broader issue of adaptation and coping strategies in response to shocks (Black et al., 2011; Alam, Alam, and Mushtaq, 2016; Kattumuri, Ravindranath, and Esteves, 2017; McNamara et al., 2018). On the other hand, migration could be a last-resort solution for households, because it is perceived as costlier than other *in situ* adaptation strategies (Wodon et al., 2014). While some studies suggest that migration and on-farm adaptation can indeed be substitutes, there is a dearth of sequential analyses assessing whether the migration decision happens before or after the implementation of alternative adaptation options (Cattaneo et al., 2019). The issues of immobility and trapped populations can also be viewed as inability to adapt, and should be examined through an adaptation lens within an integrated framework, but research to date remains scarce and fragmented. Among the few exceptions, Martinez Flores, Milusheva and Reichert (2021), who find that only people living in middle-income areas are less likely to migrate abroad after a drought (but not people living in wealthy or poor areas), argue that this is evidence that people, who under normal climatic conditions would be able to migrate, are not able to invest in adaptation mechanisms such as migration, thus sinking into poverty. Migration is just one of the many options among potential coping strategies farmers can employ to mitigate the effects of climate change. The literature has thus ignored for too long that migration is only one of many potential responses to environmental stress and that, consequently, has to be analyzed against the background of other adaptive options, which can either complement or substitute migration (Hoffman et al., 2020). Therefore, understanding how migration fits into this larger pool of coping strategies, and the temporal and causal dynamics of the migration-adaptation nexus, should be considered as research priorities.

A key take-home message that emerges from this overview is that, despite a growing body of research, there are still substantial gaps in our understanding of the complex and multi-faceted relationship between climate change and migration, and thus areas where further research is needed. Nevertheless, the nuances and differentiations revealed by this body of recent research question the conventional and simplified narrative that climate change will bring about permanent mass migration (Findlay, 2012).

2.2. Other open conceptual issues

Although not considered as part of the core analysis, it is worth recalling here a set of further areas of research that are also important to shed light on the global picture. First, the issue of future projections.

We should recall here that there is still a huge uncertainty surrounding future projections, both related to the severity of climate change and to the magnitude of future international and domestic migration flows, and more research is needed to improve the existing forecasting models. Although important, this issue remains beyond the scope of the current review that assumes as given the current state of the art on economic modeling of migration flows. Second, weather vs climate. A too often neglected fact in this literature is that short-term responses to climatic drivers differ from long-term responses. Weather shocks and climate change are not equivalent: the first are short-run fluctuations, the latter refers to permanent and long-run changes in weather patterns over time (Auffhammer et al., 2013). In turn, responses to weather shocks can differ from responses to climate change for two reasons: intensification effects and adaptation (Dell, Jones and Olken, 2014). Unmitigated levels of climate change (such as, for instance, 4°C of global warming above pre-industrial levels by 2100) would bring weather shocks well beyond those experienced in historical records. Such extremes would greatly limit *in situ* adaptation options (Gemenne, 2011). There is thus an urgent need for studies that try to fill the gap between adaptation responses to weather anomalies, which to date have been the predominant focus of the empirical literature, and responses to long-run and permanent changes in climate. The issue is further complicated by the fact that observed changes in short-term weather patterns are themselves a manifestation of gradual climate change. In this respect, a potential bridge is offered by case studies analyzing the impact of increases in the frequency of natural disasters and the way populations respond to gradual warming as well as to the risk of cumulative shocks (Cattaneo et al., 2019). To date, in fact, there have been very few such works because of a dearth of data (a point to which we return below). But this kind of medium/long run analyses, drawing on longitudinal data, is essential because it allows one to study how people respond to progressive warming and permanent shifts in climatic conditions, thus reducing the external validity gap with respect to climate change. Key issues in the more general debate on the impacts of climate change, such as non-linear effects, tipping points and critical thresholds, are currently not addressed in the existing literature, where studies usually focus on locally linear approximations of the underlying non-linear relationship (Hoffmann et al., 2020).

Third, and related, research is scant in other key channels of the climate change-migration link such as sea level rise (SLR), a phenomenon which is often prominent in the media and popular debate but still scarcely studied, even though it will certainly be a key driver of climate-related migration, with projections of 0.26–0.98-m mean sea level rise by 2100 (IPCC, 2014). Africa, and Sub-Saharan Africa in particular, is considered to be particularly at risk of coastal flooding, due to the combination of population growth and accelerating urbanization in coastal zones (Neumann et al., 2015a), and because

the likelihood of protection being successfully implemented is low (McMichael et al., 2020). We did not include sea level rise in our review because much analysis on this topic makes use of *modeled* projections of exposure rather than retrospective empirical analyses using historical data (Neumann et al., 2015b; Davis et al., 2018).[6] Fourth, future research should look at alternative outcomes, such as survival or risk management migration, voluntary vs involuntary migration, jointly rather than separately, to improve our understanding of the response heterogeneity with respect to wealth and income. More generally, gaining a more systematic understanding of the irreducible heterogeneity of the climate-migration nexus should be considered as a primary task for future research (Hoffmann et al., 2020). Fifth, more research is needed on the role played by institutions and policies in 'interfering' with the decisions to migrate in response to climatic stress. Development policies can affect migration outcomes in a way which is difficult to know *a priori*, as they could either facilitate or inhibit migration depending on the type of intervention and the related welfare outcome. For instance, while local investments in climate-resilient infrastructures or in the development of early-warning systems may reduce the need to migrate and improve *in-situ* adaptation, social protection interventions or emergency responses alleviating weather-induced liquidity constraints may make voluntary migration possible. This is especially important in order to provide evidence-based recommendations on national and international climate migration policies.

2.3. A closer look at Sub-Saharan Africa

Finally, bearing in mind the major insights from the main review, we take a closer look at recent studies with an exclusive focus on Sub-Saharan Africa (SSA), one of the parts of the world indisputably more vulnerable and exposed to climate change (IPCC, 2014) and the area where LSMS-ISA surveys (which we use as benchmark in the assessment of data gaps in household survey data to understand the climate-migration nexus) are currently implemented.

A work by Lilleør and Van den Broeck (2011) in the northern highlands of Ethiopia revealed that environmental stress shapes migration primarily through impacts on household production. Di Falco, Veronesi and Yesuf (2011) carry out a study based on a survey conducted on 1,000 farm households located within the Nile Basin of Ethiopia in 2005. They find that about 58% and 42% of farm households had used no adaptation strategies in response to long-term changes in temperature and rainfall, respectively, and that migration is one among many adaptation strategies, adopted by less than 5% of

[6] For a recent review of the literature on population exposure to sea level rise and migration, see McMichael et al. (2020).

those surveyed. Through a longitudinal household survey, Gray and Mueller (2012a) studied the consequences of drought on population mobility in Ethiopia's rural highlands, providing evidence that drought increases long-distance and work-related relocation of men, especially in land-poor households. However, severe drought reduces women's short-distance and predominantly marriage-related mobility.

Another study by Karanja Ng'ang'a et al. (2016) shows that climate change influences the livelihoods of shepherds in arid and semi-arid lands in Kenya. By analyzing data from a survey of 500 rural households in northern Kenya that relates adaptive family behavior to family migration, their analysis suggests that migration and local innovation are complementary mechanisms to ensure resilience to adverse shocks. In addition, families with at least one migrant member can employ high-cost agricultural innovations through remittances, thus improving their self-protection against weather shocks. Mueller, Gray and Hopping (2020) use census data on the migrations of 4 million individuals over 22 years to estimate the climate effects on migration in Botswana, Kenya, and Zambia. Their results for Kenya show that temperature had limited effects on migration, whereas a one standard deviation increase in precipitation caused a 10% reduction in migration. In Botswana, mobility decreases by 19% with a one standard deviation increase in temperature, and an equivalent change in rainfall causes an 11% decrease in migration. The effects of temperature appear more severe among poorly educated individuals. Rainfall shocks increase mobility in Zambia, while an increase in temperature does not affect mobility in the region. Decreases in inactivity and unemployment coincide with increases in migration, which suggest that the perspective of new job opportunities may act as a driver of climate-induced migration.

Mastrorillo et al. (2016) also argue that agriculture may function as a primary channel through which adverse weather conditions influence migration. They combine South African census data with climate data on spatiotemporal weather variability to examine South African bilateral inter-district migration flow patterns and determinants during the periods 1997-2001 and 2007-2011. The results reveal that precipitation scarcity and higher temperatures act as push effects for migration. However, the importance of the effect of climate on migration varies greatly depending on migrant characteristics, including ethnicity. In particular, the flows of black and low-income migrants in South Africa are strongly influenced by climate variables, while white and high-income migrants are weakly or not affected.

Focusing on Uganda, Agamile, Ralitza and Golan (2021) assess gender-differentiated reactions of smallholder farmers to droughts, finding that adverse weather conditions are an occasion for women to enter the commercial crop market by exploiting land from subsistence for income-generating crops, while relatively wealthier and better-educated people, especially men, are among those who benefit most from

the migration alternative. Beegle, Joachim and Stefan (2011) document that precipitation anomalies increased both the probability of people leaving the village and the distance moved in Northern Tanzania.

Mueller et al. (2020) combined NASA's high-resolution climate data with longitudinal microdata on migration, labor participation, and LSMS-ISA data (see also Section 4), to test whether climate variability affects temporary migration to rural and urban East Africa and whether climate-induced migration coincides with a lack of local job opportunities. The data included surveys conducted in Ethiopia, Malawi, Tanzania, and Uganda over six years (2009–2014). They found that climate variability significantly affects temporary migration decisions in eastern Africa, specifically that temperature and rainfall shocks cause a reduction in temporary urban out-migration. Mueller et al.'s (2020) findings are consistent with the results of Hirvonen (2016) for rural Tanzania and challenge the narrative that temporary migration acts as a safety valve in response to climatic push factors.

Grace et al. (2018) found that rainfall did not affect temporary migration rates in two Malian villages. The authors combine unique data from highly detailed stories of migration collected over 25 years in two rural communities in Mali, and document that a poor rainy season is not correlated with extreme or even above-average emigration rates. Even accounting for some known sources of variability (age, gender, etc.), a decrease in rainfall does not directly lead to a higher emigration rate. Instead, the results suggest that during low-rainfall years outmigration is lower. Henderson et al. (2017) estimate the effects of climate variability and change on African urbanization patterns over two different temporal and spatial scales: i) local, within-district urbanization for an unbalanced 50-year panel of census data from 359 districts in 29 countries; ii) urbanization patterns from 1992 to 2008 in 1,158 cities. Their estimates show that climatic conditions do affect urbanization rates, with better conditions delaying urbanization and adverse conditions leading to faster urban population growth, but that these effects are confined to a subset of about 20%-25% of Sub-Saharan African districts.

In a study already mentioned above, Martinez Flores, Milusheva and Reichert (2021) leverage high-frequency (daily) migration data on the place of origin of migrants and the time of migration, collected from the International Organization for Migration in 17 West and Central African countries over the period 2018-2019, and estimate that droughts, as measured by soil moisture anomalies during the growing season, strongly reduce the number of international migrants. As they detect these effects only in middle-income areas but neither in rich nor poor ones, they conclude that climate-induced liquidity constraints and income losses are the key mediating channels.

Finally, in a recent working paper, Di Falco, Kis, and Viarengo (2022) exploit LSMS-ISA panel data

from Ethiopia, Malawi, Niger, Nigeria, and Uganda (see also Section 4) combined with high-resolution precipitation data to study the effects of cumulative climate shocks on long-term migratory flows in Sub-Saharan Africa. Overall they find evidence of a persistent impact of droughts on rural households in these countries, which translates into a much larger effect on migration compared to the period in the aftermath of the shock as the impacts accumulate over time. The authors also detect the existence of a relationship between rainfall shortage and accelerating urbanization trends in four of the five countries considered in their analysis. At the country level, their findings contrast with previous studies that use similar multi-country micro-level data sets to examine the effect of climate shocks on rural out-migration, which found no significant or consistent migration-inducing effect of droughts in the short- and long-run. Conversely, the authors notice that their results are in line with those of macro-level cross-country studies that corroborate the contribution of rainfall deficits to faster urban development.

Overall, this review confirms that the relationship between migration and climate change in Sub-Saharan Africa is far from univocal, with some studies considering migration as a direct consequence of weather shocks and climatic changes, and others that do not find that these factors exert a clear or significant impact on people's mobility. The majority of the SSA literature focuses on slow-onset rainfall and temperature events, whereas only a few studies specify the type of migration. As an aside, we notice that there is unequal country coverage in this literature, with repercussions in terms of external validity. For instance, the Sahel region is particularly underrepresented, despite being one of the areas identified among the hotspots of climate change (IPCC, 2014).

3. Open empirical issues and data gaps

3.1 Open empirical issues

From the conceptual discussion above, a number of key open empirical issues stem:

- How to disentangle, from an empirical point of view, short-run elasticities of weather shocks on migration from the compounding effects of slow-onset, long-run, eventually permanent changes in climate and progressive warming? Most of the current works only investigate the short-run weather effects of migration and then extrapolate with respect to climate change. But this poses the problem of the already mentioned external validity gap between weather shocks and climatic change. To empirically investigate the latter, one needs to look either at longer time series in a longitudinal setting, using several lags of the weather parameters or long-run (e.g., 30-year,

which corresponds to the agreed definition of 'climate') averages, or to the cumulative effect of many repeated weather events driven by an increase in frequency linked to climate change. There are some promising approaches in the literature in this respect. For example, Cattaneo and Peri employ a technique which is now quite common in the new weather-economy literature (Dell, Jones and Olken, 2014; Burke and Emerick, 2016; Liu et al., 2022) called 'long-differences'. This approach consists of replacing annual averages of both the dependent and independent (climatic) variables of interest with decadal or multi-decadal averages of the same. This allows one to test whether the short-run relationships retrieved using annual measures also hold in the medium- and long-run, thus directly testing the external validity of the empirical findings in a climate change perspective. Cattaneo and Peri (2016) cleverly use long-differences to confirm their short-run result that warming in poor countries reduces migration (consistently with the presence of severe liquidity constraints) and find evidence in support of the persistence of this type of effect.

- As explained in the previous subsection, it is now well established that the causal link between the two phenomena is not as simple and straightforward as it once seemed to be, and there are many intervening factors (liquidity constraints, assets, *in situ* adaptation strategies such as irrigation or other on-farm investments, etc.) that have the power to alter not just the magnitude, but even the sign of the relationship. Once the analyst retrieves a statistically significant relationship between a climate shock and the decision to migrate, how can the effect be explained in light of the above-mentioned mechanisms? Recent advances in empirical micro-econometrics, such as, in particular, mediation analysis to investigate the mediating role of a variable of interest (the so-called 'mediator') in explaining a causal relationship of interest appear promising, although not yet picked up by scholars in the migration field.[7] The analysis of migration-as-adaptation, i.e., of how the decision (not) to migrate fits within a broader analytical framework on the full pool of adaptation options available to farmers in response to climate change, is also still underexplored. In this respect, while the 'rare event' nature of migratory flows is a drawback for household surveys, the potential to carry out empirical analyses of the full range of intervening factors, mediating channels, and adaptation options available to households in response to

[7] Recent examples of works leveraging the potential of this methodology to unpack the black box of causal relationships in the development field are Azzarri et al. (2022), Pace et al. (2022), and Prifti, Daidone, and Davis (2019). For a comprehensive review of the use of mediation analysis in economics, see Celli (2021).

climatic stressors using the extensive data embedded in multi-topic and multi-purpose representative surveys should not be understated.

- We also highlighted that migration is not the only possible outcome of adverse weather events. From an empirical perspective, identifying people trapped in immobility in the aftermath of a shock is even more difficult than tracing induced mobility, especially in the absence of specific information on this provided by the affected household or individual.[8] While one can separately investigate effects on a welfare measure and, for example, indirectly argue that a reduction in consumption or assets, or an increase in liquidity constraints caused by a climatic factor may have prevented migration (see Hirvonen (2016) for an example of this approach), this may not necessarily have been the case, because the mediating role of the welfare measure is usually only indirectly and separately investigated. More generally, the empirical framework on the determinants of the "migration decision" could greatly benefit from the insights and models of the well-established literature on geographical and asset-based poverty traps (Barrett and Carter, 2013; Carter and Barrett, 2006; Carter et al., 2008; Jalan and Ravallion, 2002).

- Migration is not a random event, and weather- or climate-related migration is not an exception to this rule. Self-selection comes into play when it comes to the decision to migrate or not (Carletto and De Brauw, 2012), be this decision due to climatic factors or not. Empirically, there are no clear prescriptions yet on how to address the self-selection-based endogeneity of migration,[9] with the consequence that many research designs are neither robust nor reliable. Furthermore, since migration is intrinsically a selective process, any causal inference analysis needs to check for the determinants of migration and have access to the necessary information for the identification of

[8] Incidentally, we also note that the immobility issue is not specific to climate-induced migration. It has long been known that immobility often masks the inability of people willing to move to do so, due to liquidity constraints, lack of information, absence of networks, etc. When these obstacles are removed, migration increases. A recent example of international migration triggered by a program aimed at fostering migration through improved connection and information about employment opportunities (carried out as part of an experiment implemented in Mizoram, India) is provided in Gaikwad, Hanson and Tóth (2022).

[9] Although there is a wide set of technical alternatives that could be employed to address this key issue, including, but not limited to, two-phase sampling, Heckman selection, Instrumental Variables (IV) and data-driven statistical methods, there is often limited credibility of the exclusion restriction of the proposed instruments. New data mining techniques (e.g., LASSO variable and instrument selection) can help in addressing the identification challenges connected with migration by drawing on the vast potential and richness of information of multi-topic household surveys (see, *inter alia*, Belloni et al., 2014).

both migrant (treatment) and non-migrant (control) individuals. In addition, data on pre-migration conditions are also needed (Carletto et al., 2014). While the shift from older cross-sectional studies, which were vulnerable to a wide range of potential confounders and sources of omitted variable bias, to more robust panel methods exploiting longitudinal information on household and individual movements, indeed represents a huge empirical step forward, the use of panel settings is not in itself a panacea. In fact, the issues highlighted above of self-selection, endogeneity, transmission channels, longer-run effects and persistence, reverse causality and other key empirical concerns still need to be addressed through clever research design (De Brauw and Carletto, 2012). Researchers in the field have traditionally exploited lotteries (e.g., the popular study on Saudi Arabia to Hajj Visa, Clingingsmith et al., 2009, but also the works by Gibson, McKenzie and Stillman (2011) and Gibson et al. (2018)) and other possible sets of "exogenous variations" or "natural experiments" able to mimic the hypothetical situation of a random selection of migrants. However, what they get is an estimate of the impact of migration only for the sub-group of beneficiaries (the Local Average Treatment Effect – LATE in the jargon of policy impact assessments) without "external validity". A valid alternative, in this case, could be the use of governmental policy experiments to learn about the effectiveness of alternative policy initiatives, but the latter goes beyond the scope of this analysis.

3.2 Data gaps and needs

Given the conceptual and empirical limitations of existing studies and the research priorities set out above, we have identified the main data gaps that currently prevent carrying out the proposed research agenda and possible solutions to address these data needs that can come from improvements to longitudinal, multi-topic household surveys such as the LSMS-ISA. We here start by outlining the main data gaps and needs separately for migration and weather data.

Migration data. Until recently, there was a widespread lack of basic migration data, especially in developing countries which are more vulnerable to climate change (Laczko and Aghazarm, 2009). While the situation has improved, and macro-level and international migration data are now available for a wide range of countries, disaggregated and detailed data on internal migration remain unavailable or incomplete for many low-income countries (Beine and Jeusette, 2021). This is a paradox because we know from the literature discussed above that the migration effects of climate change will primarily concern poor people living in developing countries. The paradox can only be solved by scaling up

migration data collection efforts in low- and middle-income origin countries. Despite some recent progress, there is a specific scarcity of longitudinal and long-term data from migration surveys in developing contexts. Identification issues due to the lack of panel data have long hampered empirical progress, so data collection efforts should be primarily focused on tracking individuals over time, either using self-reported data or information from proxy respondents, also to address non-response issues.

From the discussion on the tight nexus between migration and adaptation emphasized in the previous section, there is a strong case for integration, in multi-topic household surveys, between questions on migration and those on risk management, mitigation and coping strategies adopted in response to shock, such as an explicit distinction between voluntary vs involuntary migration, survival vs risk management migration, immobility due to *in-situ* adaptation vs immobility due to liquidity constraints and inability to move.[10] These nuances and amendments to the existing surveys and modules would greatly enhance the scope for empirical applications in this active area of research, while being relatively low-cost and easy to implement and collect.

As far as short-term, temporary and seasonal migratory flows are concerned, not only should data be longitudinal, but they should also be high-frequency, i.e., they should be collected annually. As emerged from the meta-analysis of Beine and Jeusette (2021), the frequency of the data employed plays a significant role in determining the findings of econometric analyses: data sampled at higher frequencies tend to support the case of an effect on mobility more, since migration measures spread over several years or longer periods are less able to capture short-term migratory flows driven by climatic hazards.

The use of direct measures of mobility, rather than indirect proxies, has often also been stressed as important but remains the exception rather than the rule. Following Beine and Jeusette (2021), an example of direct measure of mobility can be found in survey data where people are directly asked about their migration history, whereas an indirect measurement means that migration is inferred rather than observed, as in the case of differences in migration stocks reconstructed from censuses. Importantly, econometric analyses using measures of mobility that are computed or derived from proxies tend to find

[10] A caveat is in order here to remind readers of the potential differences and inconsistencies between 'stated' and 'revealed' migration preferences, which compound over the already complex and multi-faceted nature of the migration phenomenon, that can take many different forms both across space and over time. The issue is also related to the heterogeneity of the climate risk perceptions of the individuals interviewed.

less empirical evidence in favor of a causal effect of environmental shocks on migration (Beine and Jeusette, 2021). The use of migration flows as the dependent variable in the regressions increases the probability of finding an impact, and data on direct measures of migration should be collected accordingly. *Ex post* counterfactual policy evaluation of development and social policy interventions aimed at either favoring or reducing weather-induced migration flows is also scant. There is a need for data observed on such programs to improve our understanding about the role of policy in mediating the causal relationship between climatic shocks and human mobility. As a complement to that, the collection of detailed community-level data to supplement household survey data on the roll-out and implementation of such programs is also a key element to be considered.

Last but not least, the growing availability of big data and citizen-generated information has spurred a debate on their potential integration or complementarity with more traditional data collection methods, such as census and surveys, to fill migration data gaps. In principle, these new data sources could massively improve the quantity of data available to study climate change and migration. Entities such as the European Commission and the International Organization for Migration have already started to assess the potential of sources of big data. Among the most prominent examples of these non-traditional data sources: mobile phone call detail records (CDR); Internet activity such as Google searches; online media content; geo-referenced social media activity, which can be obtained via advertising platforms offered by social media (IOM, 2018). There are also some first recent scientific works based directly on these sources. Lai et al. (2019) employed a massive data set of 72 billion anonymized CDRs in Namibia from October 2010 to April 2014, to explore how internal migration estimates can be derived and modeled from CDRs at subnational and annual scales. As for social networks, Spyratos et al. (2019) used anonymized and publicly available data provided by Facebook's advertising platform to estimate the number of Facebook Network (FN) "migrants" in 119 countries of residence and concluded that these estimates could be used for trend analysis and early-warning purposes. Specifically concerning climate change, some have highlighted that in combination with field-level data derived from household surveys and key-informant networks, big data could be used to detect how sudden-onset natural disasters and progressive environmental change impact migration patterns (Franklinos et al., 2020). Along these lines, for example, Lu et al. (2016) used anonymized CDR from a mobile network provider (Grameenphone) to retrieve the geographical position and movements of users, so as to be able to examine the human mobility effects of the 2013 Mahasen cyclone in Bangladesh. Finally, for an interesting comparison between mobile phone and census data, see Wesolowski et al. (2013) and Kirchberger (2022) for a

discussion of their potential for research on internal migration. More generally, given their increasing availability and huge potential, there is a clear need to invest more in research aimed at developing methods for improving integration and interoperability of household surveys with these new data sources.

Weather data. To investigate climate-related migration outcomes, accurate and georeferenced weather information is needed. However, most household surveys include, at best, self-reported measures of weather shocks based on individuals' recalls, which can hardly be reliable or comparable given their subjective nature. For this reason, household data from multi-topic surveys are almost always autonomously integrated with external weather information. The main public domain sources of weather data include NASA *Modern-Era Retrospective analysis for Research and Applications* (MERRA-2), the *Terrestrial Air Temperature and Precipitation* database from the Center for Climatic Research at the University of Delaware, and the *High-Resolution Gridded Datasets* from the Climatic Research Unit of the University of East Anglia. Remote sensing weather data sets, which can take the form of gridded, satellite, or reanalysis data, have been used in many studies leveraging LSMS-ISA data to address weather- and climate-related research questions in Sub-Saharan African contexts (see, among many, d'Errico et al., 2019; Letta et al., 2018; Mueller et al., 2020; Di Falco et al., 2022).

While this integration is typically carried out directly by the research team, this practice can be suboptimal for several reasons. First, the intrinsic diversity of weather data products. For instance, satellite data provide less accurate data than ground stations in most locations and do not extend as far back in time. Gridded data, on the other hand, aggregate data from ground stations via interpolation and across a given space. This works well in developed countries, where there is wide and uniform coverage of weather stations across the entire territory, but not so much in developing contexts, where often gridded data aggregate weather information from a few old stations spread across the country. Sparse coverage is a serious issue given the interpolation method adopted by gridded products. Finally, entry and exit of stations (quite common, especially in poorer countries) can be endogenous and represents an additional source of measurement error of true weather conditions experienced by people.[11] Such diversity in weather data products can affect econometric estimates of the relationship between climatic events and a given socioeconomic outcome of interest. Second, the need for spatial anonymization for privacy protection in household surveys, usually implemented through a random offset of true household

[11] See Auffhammer et al. (2013) and Dell, Jones and Olken (2014) for further discussion. For a comprehensive overview of the availability and quality of climate data in the context of Africa see, instead, Dinku (2019).

geocoordinates, can introduce mismeasurement when integrating them with remote sensing weather data.

In a new study based on a pre-analysis plan, Michler et al. (2022) employ 90 linked weather-household data sets that vary by the spatial anonymization method and show that, as the spatial resolution of most weather data produce is too coarse, spatial anonymization techniques have an overall small effect on the estimates of the weather-agricultural productivity relationship and do not introduce substantial mismeasurement. Depending on the specific type of weather data, however, measurement error can become significant, especially for higher-resolution data products. Importantly, Michler et al. (2022) also find that estimates of weather's impact on agricultural productivity vary substantially in sign, significance, and magnitude, across different weather data sets for the same spatial anonymization technique. For these reasons, caution is in order when integrating household surveys such as the LSMS-ISA with external weather data, and the first-best would be to have high-resolution weather data already embedded in the survey data set.

4. LSMS-ISA data assessment

To draw concrete operational implications from the review above, we start by outlining what the implications would be for one of the international survey programs that has been at the forefront of the methodological debate on data collection in low- and middle-income countries in the past 15 years or so. The LSMS-ISA program was launched in 2009 with funding from the Bill and Melinda Gates Foundation and the explicit aim is to fill the gaps in agricultural data through close collaboration with the national statistical offices (NSOs) of partner countries. The program is based on the implementation of multi-topic, nationally-representative household longitudinal surveys and, to date, has been carried out in eight Sub-Saharan African countries, namely Burkina Faso, Ethiopia, Mali, Malawi, Niger, Nigeria, Tanzania, and Uganda.

LSMS-ISA survey panels are administered approximately every 1 to 3 years. In the LSMS-ISA program, not only original households are revisited each wave, even if they relocate within the country, but also individual household members who split off from previously selected households are tracked and included in subsequent waves. This intertemporal aspect of LSMS-ISA surveys, therefore, unlocks the potential for the analysis of internal and rural–urban migration patterns, among other things (Carletto and Gourlay, 2019).

4.1 Key limitations of the LSMS-ISA data sets

Given the features of the LSMS-ISA program and based on our previous critical overview, we identify the following as the main limitation of LSMS-ISA data collection to empirically disentangle the climate-migration nexus: questionnaire design; sample size and statistical challenges; and respondents' issues. In the rest of this section, we focus on each of these areas in turn.

Questionnaire design. Although the LSMS-ISA questionnaires are usually highly standardized across surveys and countries, the information is sparse, and there are inconsistencies not just across countries, but also across different surveys within the same country. The lack of consistency in terms of the set of questions included to detect migration and/or define migrants is certainly the first element to be considered for a revision of the LSMS-ISA collection aimed at improving data collection on migration. It also explains why there are only a couple of cross-country investigations on the climate-migration links which uses LSMS-ISA, the analysis by Mueller et al. (2020) and the one by Di Falco et al. (2022). In both cases, due to comparable and precise information about migration not being available for all the countries, the studies have to rely on proxies to define different types of migrations. Specifically, Mueller and colleagues exploit questions regarding the absence of individuals during the follow-up survey to define temporary migration as whether an individual present at baseline reported migrating for at least one month in the previous twelve. Of course, without knowing, in most cases, either the destination or the reasons for migrating, they had to make a strong assumption on the equivalence between temporary absence from the household and outmigration. See below (subsection 4.2) for further discussion on this point. The study by Di Falco and colleagues focuses on long-term migration instead, and thus individuals are proxied as migrants if households report them to have left between two visits or waves of the survey and who were not observed to return to their household during the time of analysis. In this specific case, the assumptions made are even stronger than those implied by Mueller et al. (2020), as the definition of migrants includes individuals that left the household because they married.

Sample and statistical issues. Migration is, statistically speaking, a rare event. As reported below, the only five climate-migration studies using LSMS-ISA data have very small samples. This is unsurprising, as in a normal clustered sample design typical of multi-topic surveys, the expected number of households associated with emigration may be very low (Carletto et al., 2014). To better identify rare events, two potential approaches are disproportionate sampling and two-phase sampling. However, both sample designs require some prior knowledge of migration in the population and are not easy to implement as

part of a household survey such as those of the LSMS-ISA collection, which are meant to be, by their very nature, multi-topic and nationally-representative, and not exclusively targeted to the study of migration. In this respect, the relatively small sample size of most LSMS-ISA surveys often makes them unsuitable for the study of migration, as the standard LSMS-ISA multi-stage cluster design is unlikely to sample a sufficiently large number of households with migrants (De Brauw and Carletto, 2012).

Respondents' issues. More broadly related to data collection, Lucas (2021) notes that collecting migration data is essentially limited to two approaches: asking individuals about their migration experiences or asking remaining household members about those who left, and both present limitations. The former approach, in fact, provides little information about the household that the migrant left; the latter assumes that the respondent knows the current whereabouts and activities of the migrated household members, and memory about the list of those who departed may prove selective.

In addition, as noted by Kirchberger (2022) in her recent review, even when panel household surveys aim to track respondents, household surveys can still suffer from high levels of attrition. Other general shortcomings are: i) questions about migrants need to be answered by a proxy, generally a family member, which may introduce many imperfections and substantial bias (Carletto et al., 2014); ii) the double-counting of migrants, especially those who can be claimed as members in other households' rosters; iii) the difficulty in classifying the type of migration: temporary (short-term) migration and (long-term) permanent migration are usually distinguished by an arbitrary threshold or time criterion set by the analyst. Return migration, seasonal migration, and circular migration can also be difficult to distinguish from one another (De Brauw and Carletto, 2012).[12]

Finally, specifically concerning climate-related hazards, it is unlikely that migration caused by a fast-onset climatic disaster would be captured in an LSMS-ISA survey, given the localized nature of these types of events and unless the survey takes place soon after the shock (De Brauw and Carletto, 2012).

[12] *Seasonal* migrants are those who leave for a specified period of time each year and should be identified through questions about repeated, short migration spells. *Return* migrants migrated at some time in the past and have returned to the country or household somewhat permanently. *Circular* migrants are those who have returned but plan to leave again for a significant period of time, or repeatedly migrate for long spells.

4.2 Limited empirical research uses LSMS-ISA data sets to explore the climate-migration nexus

Our literature search on the number of works on migration and climate change which used LSMS-ISA data returned only five papers, four of which published in peer-reviewed journals: Ocello et al. (2015); Kubik and Morel (2016), Mueller at al. (2020), Becerra-Valbuena and Millock (2021), and the recent working paper by Di Falco et al. (2022).[13]

Ocello et al. (2015) and Kubik and Morel (2016) both focus on Tanzania, and employ the LSMS-ISA National Panel Surveys. While the first looks at both the 2008-2009 and the 2010-2011 waves (although the latter is used only to identify migrants), Ocello et al. (2015) only employ the first. Both also share similar identification strategies (a two-stage setting with an IV probit model for the former, logit regression the latter) based on a cross-sectional setting which is not invulnerable to identification threats. Despite the similarities, they arrive at somewhat contrasting results: Kubik and Morel (2016) find that a reduction in agricultural income caused by a weather shock *increases* the probability of internal migration. However, this effect is significant only for middle-income households, whereas it is insignificant for the poorest and the richest households, confirming that the decision to migrate as an adaptation strategy depends on liquidity constraints and initial endowments, with the poorest households that cannot afford migration costs, while the richest ones can afford *in-situ* adaptation strategies, such as irrigation or drought-resistant crops. Ocello et al. (2015) document that being exposed to droughts or floods or crop diseases is associated with an overall decrease in the likelihood of inter-district mobility, with the exception of low-educated individuals.

Mueller et al. (2020) employ the LSMS-ISA data from four countries, namely Ethiopia, Malawi, Tanzania and Uganda. They combine these household panel data with climatic data from NASA's MERRA to investigate temporary migration responses to weather anomalies in the East African context. Using a linear probability model, they find that climate impacts tend to *decrease* outmigration and, perhaps surprisingly, are most pronounced in urban areas.

Becerra-Valbuena and Millock (2021) combine LSMS-ISA Malawi surveys with satellite weather data covering the timespan 2000–2016 to estimate the probability of migration for reasons related to work and marriage separately for men and women. They find that overall droughts inhibit marriage-related

[13] We here refer only to studies exclusively focusing on the causal links between climate change and migration, and exclude works devoted to other research questions that incidentally find climatic impacts on migration decisions.

migration for women, but increase migration of children for work, especially for boys. To carry out their analysis, they use the migration-related questions on where the individual lived before moving to the current area of residence, when he/she moved, and the stated motive for doing so. Although this allows one to retrieve the district of origin and destination as well as the time of migration of individuals interviewed, they notice that the lack of information at origin before moving is a limitation for their study.

Di Falco et al. (2022) use LSMS-ISA data to construct a multi-country panel data set covering Ethiopia, Malawi, Niger, Nigeria, and Uganda that is merged with high-resolution gridded precipitation historical records from the Climate Research Unit to analyze the effects of cumulative drought shocks on the decision to migrate in rural households. While confirming the existence of an immediate, although small, impact on migration decisions in the aftermath (i.e., the subsequent year) of a severe and extreme drought shock, they interestingly show that this impact is long-lasting, increasing migration for at least five years after the shock occurs, and not even fading or diminishing over time. Furthermore, they find that the effect of multiple recently experienced droughts (past five years) accumulates over time, which results in a much higher number of migrants than one would expect based on the immediate effect of the shock only. The authors emphasize that this has relevant implications for the study of climate-induced migration and make a plea for advancing the research on the cumulative impacts of climate change on determining migratory flows in the long-run while at the same time improving the availability of detailed data on migration.

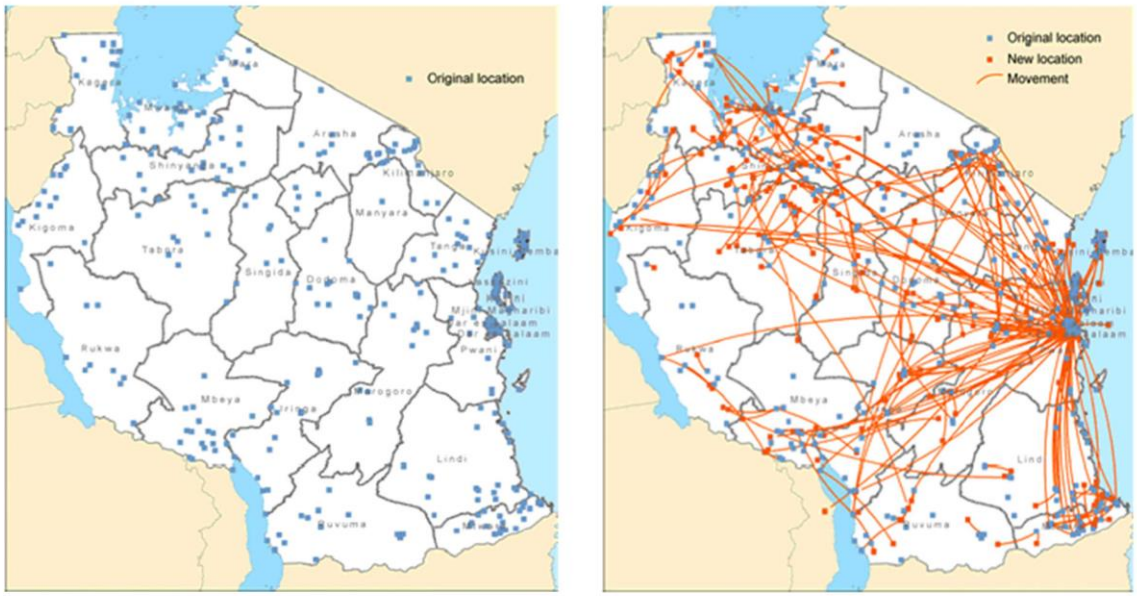
The fact that out of the vast and growing literature reviewed before, only five studies employ LSMS-ISA data (and even with conflicting findings), is a clear indicator of the currently limited capacity of the LSMS-ISA data sets to provide a basis for meaningful analysis on climate change and migration. Figure 1 below provides an idea of the type of migration tracking that is possible using the LSMS-ISA data.

Let us focus, as a benchmark (see below for a comparative analysis of all LSMS-ISA surveys), on the Tanzanian National Panel survey, which was used by three out of the five studies above. All the available migration information in the questionnaires is essentially limited to a few questions in two sections in the Household Questionnaire, Modules B and G.[14] Module G, named "Children Living Elsewhere – Migration" contains some information on households responding affirmatively to the question: "*Do you have any children 15 and older who live elsewhere (outside this household)*?" such as information on the

[14] Cf. https://microdata.worldbank.org/index.php/catalog/76/related-materials. We use questionnaires from the second round (2008-2009) as the benchmark here.

most recent job, education level, and money sent by the absent individual (who is not necessarily a migrant). No questions are asked about the reasons which prompted her/him to move in the first place.

Figure 1. Household between-wave mobility – Tanzania National Panel Survey



Source: Carletto and Gourlay (2019)

In addition to this module, some basic questions are also asked in Module B of the household questionnaire, namely:

- B.9: "*For how many cumulative months during the last 12 months has [NAME] been away from this household"?*
- B.10: "*What was [NAME]'s main occupation for the past 12 months?"*
- B.24: "*For how many years have you lived in this community*?"
- B.25: "*From which districts did you move*?"
- B.26: "*Why did you move here*?"
- B.27: "*In which district were you born*?"

This is why both Ocello et al. (2015) and Kubik and Maurel (2016) had to rely on some assumptions to identify migrants. In Ocello et al. (2015), a migrant was defined as a person aged 15 or older who had moved from one to another district in the five years before the interview, while migrants who moved into or out of the country were excluded from the analysis, given the focus of the study on internal migration. Specifically, the authors identified origin and destination districts using questions B.24 and B.25 reported

above, and considered respondents living in the community for less than five years as migrants. After this selection process, their sample included 2,883 individuals aged 15 or above, only 6% of whom migrated from one Tanzanian district to another in the period between 2004 and 2008. Kubik and Maurel (2016), instead, in the absence of an explicit question on permanent migration in the data set, exploited the second wave of the survey collection (2010-2011) to identify migrants, by directly comparing the place of residence of all household members in the first and the second waves of the survey and identifying residential moves based on the GPS coordinates of the place of origin and destination. Following this strategy, they defined their outcome variable of interest as a migration dummy equal to one for households with at least one member who permanently moved out of the original village between 2008/09 and 2010/11, and found that 14 percent of households had at least one migrant between the two waves. Note also that Kubik and Maurel (2016), by design, observe internal migration only.

In the subsequent waves of the Tanzanian NPS collection, some changes were implemented. From Wave 2 (NPS 2010-2011) on, Module G on children living outside the household was dropped. In Wave 3, NPS 2012-2013, an amendment was added among the roster of possible replies to the following question in the *Shocks* Section R:

R.6: "*What did your household do in response to this [SHOCK] to try to regain your former welfare level?*"

Among the possible replies, there is the following choice: "*Household member migrated*". This option, however, was not present in the subsequent, and currently final, wave of the collection, NPS 2014-2015. The Tanzania example, chosen as its surveys were used by the studies reviewed above, is emblematic of the limitations and internal inconsistencies involving migration data in most surveys of the LSMS-ISA collection.

Prompted by the reply featuring migration as a coping strategy in the Tanzania surveys, we carried out a screening of all the questions and answers potentially related to the climate-migration nexus that are currently available in the entire LSMS-ISA collection. The detailed outcome of this screening is reported in Table A.1 in the Appendix. The migration-as-coping-strategy option is actually present in the shock questionnaires of many LSMS-ISA surveys in other countries. Interestingly, across the whole the LSMS-ISA project, the most explicit questionnaire reference to the climate-migration nexus can be found in the Uganda collection, in rounds 2008-2009, 2009-2010, 2010-2011, 2013-14, and 2015-2016 of the panel, where the following question appears:

Q.3.18: "What was the main reason for moving to the current place of residence?"

And, among the options, there is the following possible reply: "*Drought, flood or other weather-related condition*". This is exactly the type of question that would enable more research on the climate-migration relationship. Unfortunately, however, this question disappeared from the latest rounds of the Uganda panel collection and is currently not found in any other collection of surveys across other countries (cf. Table A.1). Our general conclusion, therefore, is that given the current limitations of the LSMS-ISA data sets, there is limited scope for these data to help shed light on some aspects of the climate-migration relationship. However, we believe that a change of perspective on some key issues and relatively straightforward amendments to the questionnaires could greatly enhance the potential of this multi-topic household survey collection in this research field. This is the focus of the next section.

5. Adapting LSMS-ISA surveys to collect literature-based migration data

In this section, we elaborate on what is the opportunity window for: i) current LSMS-ISA surveys to enhance the understanding of the climate-migration nexus; ii) adapting future LSMS-ISA surveys to collect migration data and position itself as a leading data collection program for the field.

In particular, we identify promising areas to which, with minor improvements, LSMS-ISA surveys can greatly contribute, including the issues of migration as adaptation, climate-induced immobility and potential migrants, the role of mediating channels and contextual factors. Finally, we provide an assessment of the potential integration of LSMS-ISA surveys with other non-traditional data sources. Clearly, given the reliance on longitudinal migration information tracking individuals and households over time (and across space), all these data-related opportunities crucially depend on the continuation of existing panels and the launch of new ones, which should go in parallel with efforts towards improving questionnaire design and interoperability with other data sources.

A. Look at (im)mobility in the broader framework of adaptation to climate stress

While the issue of small sample sizes of households with migrants, stemming from the 'rare event' nature of migration, is an intrinsic shortcoming of general-purpose multi-topic representative surveys, a change of perspective on the issue can help in thinking about new research directions. In particular, our review has emphasized that the potential immobility traps of climate-related hazards are at least as important as the mobility effects triggered by such events. In this respect, household surveys could be employed not

only to look at the migratory flows causally linked to weather anomalies and climatic disasters but also, and perhaps especially so, to the relationship between such events and the presence of potential immobility traps associated with adaptation failures. A useful tool in this respect would be an *ad hoc* section on migration-as-adaptation embedded within a broader Adaptation Module, with particular emphasis on questions investigating the reasons (e.g., the role of liquidity constraints) that hampered the implementation of household- or individual-level coping strategies, including those migration-related.

Migration can be seen as one among a pool of household adaptation strategies in the face of environmental change. The study of *in-situ* adaptation strategies, therefore, should be seen as complementary to the adaptive decision to migrate. McCarthy (2011) provided a set of key indicators and modules to supplement LSMS and LSMS-ISA survey instruments based on a taxonomy of household agricultural practices and investments that can contribute to adapting to climate change (the so-called sustainable land management, SLM). These include agroforestry investments, reduced or zero tillage, use of cover crops, and various soil and water conservation structures. There are often long-term benefits to households from adopting such activities in terms of increasing yields and reducing the variability of yields, making the system more resilient to changes in climate.

The implementation of a comprehensive *Adaptation* module capturing these aspects as well as other insights from resilience and vulnerability studies (Magrini et al., 2018; D'Errico et al., 2019) would represent a clear added value for household surveys. It would allow one to distinguish between migration as adaptation mainly implemented as a strategic risk diversification strategy by richer and better-endowed households *vs* survival migration adopted as a last-resort option by the poorer households, and hence enhance our understanding of the nature of migration as voluntary or involuntary. It would also have important implications for studying adaptation policies to climate change in rural developing contexts in Sub-Saharan Africa. For example, the systematic inclusion, in the roster of potential answers to the question on coping strategies, of the option "*Drought, flood or other weather-related condition*" as in question Q.3.18 of the earlier rounds of the Uganda collection, which we mentioned above, would be a straightforward way to collect more information on climatic push factors. Even if a module should not be seen as a viable solution, the collection of additional questions and to make up for the current lack of an integrated framework on adaptation in household surveys such as the LSMS-ISA is in any case strongly encouraged.

B. Investigate the socio-economic channels and contextual factors driving climate-related (im)mobility

A complementary and parallel solution to the *Adaptation* module suggested above is the development of an *Intention-to-migrate (ITM)* module on potential migrants to investigate the issues of immobility and climate-induced reductions in migratory flows. Such an *ITM* module would draw from the available evidence on climate risk perception (Helbling et al., 2021; Koubi, Stoll and Spilker, 2016; Zander, Richerzhagen and Garnett, 2019) and, in order to investigate the potential of climatic hazards to trap people in immobility, its framing should also be inspired by the theoretical insights of the sound literature on asset-based and geographic or shock-driven poverty traps (Barrett and Carter, 2013; Carter and Barrett, 2006; Carter et al., 2008; Jalan and Ravallion, 2002; Letta et al., 2018). With *ITM* information at hand, it would also be possible to fully unleash the potential of one of the main advantages household surveys hold over other data sources on migration, the possibility of assessing the role of transmission mechanisms and contextual factors that affect the magnitude, or even the direction, of the climate-migration link. The LSMS-ISA collection, given its multi-topic nature, can be particularly informative on these issues, because the analyst can fully exploit the wealth of information available about household demographic, economic, and geographic characteristics to investigate a broader range of issues involving the causal links between poverty, agriculture, climate and the (in)ability to migrate.

C. Other possible data improvements in longitudinal surveys

Migration data. The two *Adaptation* and *ITM* modules proposed above imply a change of perspective to investigate immobility and transmission mechanisms. But we also call for a series of other data improvements in longitudinal household surveys such as those of the LSMS-ISA. These surveys, in fact, exhibit a clear potential given their intertemporal nature (Carletto and Gourlay, 2019), which also allows them to track over time, and include in the subsequent waves, households that relocate within the country, as well as individual members who split off from previously selected households. A possible additional tool to enhance this traceability is the design and implementation of an "associate module" meant to keep track of "*people who are not members of the surveyed households but who are somehow associated with them, either because they contribute to the household standard of living and/or because they moved out of the household, and/or simply because they are close relative"* (Beauchemin, 2020). A complementary solution could be to proxy this information by collecting histories and retrospective data in panel waves covering years between surveys. In any case, the data gaps on migration require one to track people over time and across space, either directly or indirectly. Finally, a third route could consist of establishing a

functional link with proximate data collection on national and local patterns of local labor mobility.

Weather data. Thanks to their panel nature, LSMS-ISA surveys can capture repeated weather shocks, cumulative weather risk, and their potential impact on migration outcomes. From a data collection perspective, to maximize this potential, it would be necessary to incorporate, within multi-topic surveys, a built-in and comprehensive set of (spatially and temporally) high-resolution weather data, ideally collected *in situ* during the data collection efforts (for instance, through weather sensors), which should: i) not be limited to temperature and precipitation, but also incorporate other key weather variables such as humidity, windspeed, etc.; ii) include *ad hoc*, agriculture-oriented weather information, such as weather indicators constructed on the basis on crop-specific and local growing season calendars; iii) also include, in addition to weather data, all the equivalent climate variables, based on the long-run averages (e.g., 30-year) of the weather time series. Should such weather data collection *in situ* be unfeasible due to timing or budget constraints, efforts could be devoted to the integration of existing surveys with crowdsourced weather data (Minet et al., 2017; Muller et al., 2015; Overeem et al., 2013), to obtain the maximum possible spatial and temporal granularity of the climate information. The provision of a set of built-in weather data would prevent risks deriving from independent user integration with external remote sensing weather data, i.e., measurement error due to spatial anonymization and the sensitivity of econometric estimates to the specific weather data product chosen by the researcher (Micher et al., 2022), as well as the use of self-reported weather shocks based on the perceptions of the individuals interviewed – such as in Ocello et al. (2015) – whose accuracy remains questionable. The inclusion of longer-run climatic measures and time series would also allow the implementation of more recent and sophisticated techniques tailored to bridge the external validity gap between weather and climate, such as long differences or the inclusion of several weather lags in the regression models.

Lastly, while standard nationally-representative household surveys such as the LSMS-ISA are clearly disadvantaged with respect to the possibility of investigating the migratory outcomes of localized sudden-onset weather shocks, which require *ad hoc* post-disaster surveys, the use of 'mixed-mode' data collections solutions, such as the alternation of standard face-to-face surveys with higher-frequency phone-survey interviews, would allow one to obtain not only more timely and frequent longitudinal information in general but also, in case a sudden shock occurs, the collection of basic migration data in the aftermath of the shock itself, and to do so in an easier and less expensive way compared to the complexity associated with the implementation of a swift *ad hoc* survey in the area exposed to the disaster.

D. Integration with non-traditional data sources

As for the opportunities offered by the integration with non-traditional data sources, also known as 'digital trace' data (Kirchberger, 2022), such as big data and citizen-generated data, our assessment is that there are both pros and cons, and that while, at the moment, improving interoperability of household surveys with non-conventional data presents complex issues, this is likely to be the way to go in a not-so-far future. On the one hand, big data, such as mobile phone data or smartphone app data, have indeed the potential to complement traditional data and address significant spatial and temporal gaps. As emphasized by the International Organization for Migration (IOM, 2018), the main strengths of these new data sources lie especially in their wide and continuous coverage, flexibility, timeliness, frequency, high spatial, relatively low cost, and their potential to track temporary, circular, and seasonal patterns of migration, which are difficult to capture through traditional sources. Additionally, big data can be a promising tool for better ex-ante sample design, such as first-stage sample selection, and allow one to compute new covariates that would otherwise be costly or difficult to collect at scale, such as labor market referrals, social networks, or mobility and social contact (Kirchberger, 2022). On the other hand, the use of big data comes with significant challenges, among which: i) ownership by the private sector; ii) privacy, data protection and ethical issues in using data automatically generated by users, and human rights concerns; iii) their volume, complexity and "noisiness"; iv) the fact that big data reflect behavioral patterns which may not be representative of the population (selection bias); v) reliability of the self-reported information on social media; difficulties in applying statistical definitions of migration.

Using the case study of a data science challenge involving West African mobile phone data, Taylor (2016) argues that big data carries with it the dual risk of rendering certain groups invisible, and of misinterpreting what is visible and, in addition, raises concerns about the lack of information concerning the context of behaviors and activities 'observed' using big data analysis. Others have argued that the distance between the researcher and the research looms large for remotely generated data, posing challenges to validity and ground truth, as well as for the reliability and interpretation of research results (Kraly and Hovy, 2020). Operationally, while the potential for using such data to better understand migration dynamics has yet to be fully explored, integrating multi-topic household surveys with varied sources of big data requires not only addressing the significant technical and ethical challenges just highlighted but also the development of new methodologies that consider complex interactions over differing geographic and temporal scales (Franklinos et al., 2020). Furthermore, to leverage big data as a meaningful source of information for migration analysis, national statistical offices would need to work

with all relevant stakeholders to manage the process of data production. (IOM, 2018). These are hard challenges, but non-conventional data sources offer such great potential in complementing (not in substituting) survey data that, at some point, these challenges will have to be faced. Our assessment, therefore, is that while these challenges and drawbacks currently make their potential combination with household surveys challenging in the short-run, these sources appear promising for the future, especially because of their ability to provide a large amount of more timely and granular data.

6. Conclusions

It is easy to envisage that, as climate change intensifies, the climate change-migration nexus will keep gaining prominence in the international agenda. In parallel, the empirical literature will keep growing. Further refinements to the conceptual framework, as well as developments in econometric techniques, will shed new light on the relationship between these complex, multifaceted phenomena. However, all of this cannot provide concrete benefits for policy making without closing the existing data gaps.

Based on the empirical review, we have identified the main data gaps on the climate-migration nexus. Using a household survey program currently at the forefront of methodological research, the LSMS-ISA project, we then identified the limitations and opportunities for household survey data to enhance our understanding of the causal relationship. A summary of this assessment is reported in Table 1, which provides a list of the most relevant conceptual and empirical issues, with the corresponding data gaps and a set of initial proposals to boost the potential of household surveys such as the LSMS-ISA. We have stressed that household surveys currently allow limited exploration of the climate-migration nexus. At the same time, we have also documented, in light of the open issues and research gaps in the literature, the great potential that LSMS-type surveys hold to help address some of the most policy-relevant research questions in the field. Our proposals are twofold: conceptual and operational. Conceptually, we call for researchers to make use of these data to investigate some of the most important but still unclear aspects of this nexus, such as the role of immobility, the complementarity or substitutability between migration and other adaptation strategies, the migration potential of cumulative slow-onset events. Operationally, we propose to integrate multi-topic, multi-purpose, longitudinal household surveys with additional pieces of information enhancing both the quality and quantity of the information collected. In particular, with only slight modifications to the current questionnaires, such as short modules on adaptation and intention to migrate, the collection of migration histories or associate modules, and the integration of face-to-face surveys with phone surveys to increase the frequency of the longitudinal information, it would be possible to maximize the potential of these tools in a cost-effective way.

Table 1. Summary of the literature-based assessment of data gaps

Conceptual issues	Empirical issues	Data issues	LSMS-ISA issues	Proposals
Fast- *vs* slow-onset events	Different migration outcomes depending on the type of event	'Rare event' nature of migration in household surveys; need for high-frequency data and long panels; need of *ad hoc* surveys for fast-onset shocks	Small migrant samples; lack of high-frequency data and long panels	More focus on immobility and cumulative slow-onset changes; 'mixed-mode' data collection solutions combining standard and phone surveys
Direct *vs* indirect effects	Identification of channels	Need for multi-topic and multi-purpose data	None, it is its main added value	More empirical research using *ad hoc* tools (e.g., mediation analysis) to leverage this added value
Internal *vs* international migration	Inconclusive evidence of the two phenomena and their interconnectedness (the climate migration chain)	Need for longitudinal microdata on internal and international mobility	Lack of consistent information (across countries, within countries, over time)	Collection of migration histories and more systematic retrospective/recall data in panel waves for in-between years; associate module; potential links with complementary labor mobility data
Liquidity constraints, mobility *vs* immobility	Disentangling the relationship between migration, wealth and resources	Dearth of data on potential migrants, intention-to-migrate, stated *vs* revealed preferences, reasons for migrating	Small migrant samples; indirect proxies/measures for migration; no information on potential migrants	ITM module; empirical focus on immobility traps
Migration as adaptation	Understanding the linkage between agricultural practices, *in situ* adaptation and migration; voluntary *vs* involuntary migration	Data gaps on a set of indicators capturing the interconnectedness between farmers' adaptation and decisions to migrate	Lack of an integrated and comprehensive framework on adaptation	Adaptation Module (in which migration appears as a strategy among a pool of other adaptation options)

As noted by scholars and practitioners,[15] adding modules to existing surveys such as the LSMS-ISA has a non-negligible advantage in terms of both timing and cost, as it involves only the relatively small marginal cost (compared to the total survey cost) of adding questions to an ongoing survey program already funded and underway. In the medium term, solving technical and ethical challenges related to the interoperability with non-conventional data sources would unleash even more innovations and opportunities. For the moment, we see clear scope for general multi-purpose household surveys to play a leading role in the climate-migration field, as these tools hold key advantages over censuses and other administrative data sources due to their comprehensiveness and flexibility to collect more detailed data. Our review calls for the exploitation of these advantages.

[15] See, for example, here: https://migrationdataportal.org/blog/household-surveys-key-potential-source-data-migration.

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* To help readers, we report, next to each reference, a number in bold and square brackets depending on the specific topic to which each reference belongs. The legend is as follows: [1] Migration and climate change; [2] Migration data sources, gaps, and methods; [3] Climate change impacts and weather data; [4] Other topics.

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Appendix

Table A.1. Relevant information for the climate-migration nexus

in standard LSMS-ISA collection questionnaires

Survey ID Number	Survey Name	Country	Questions/answers/sections potentially related to the climate-migration nexus
BFA_2014_EMC_v01_M	Enquête Multisectorielle Continue 2014	Burkina Faso	**Question CS4:** Quelle a été la stratégie adoptée par le ménage après le [CHOC] pour faire face à la situation? **Option 11:** Migration d'un ou plusieurs membres du ménage
ETH_2011_ERSS_v02_M	Rural Socioeconomic Survey 2011-2012	Ethiopia	**Question 8.4:** What did your household do in response to this [SHOCK] to try to regain your former welfare level? **Option 8:** Household members migrated
ETH_2013_ESS_v03_M	Socioeconomic Survey 2013-2014	Ethiopia	**Question 1.22:** Why did [NAME] leave this household? **Option 4:** Left to find better land **Option 5:** Health reasons **Option 6:** Security reasons
			Question 1.30: What was the most important reason [NAME] migrated away? **Option 4:** Left to find better or more land **Option 5:** Health **Option 7:** For security
			Question 8.4: What did your household do in response to this [SHOCK] to try to regain your former welfare level? **Option 8:** Household members migrated
ETH_2015_ESS_v03_M	Socioeconomic Survey 2015-2016	Ethiopia	**Question 1.22:** Why did [NAME] leave this household?

			Option 4: Left to find better land **Option 5:** Health reasons **Option 6:** Security reasons
			Question 8.4: What did your household do in response to this [SHOCK] to try to regain your former welfare level? **Option 8:** Household members migrated
ETH_2018_ESS_v02_M	Socioeconomic Survey 2018-2019	Ethiopia	**Question 1.23:** Why did [NAME] leave this household? **Option 4:** Left to find better land **Option 5:** Health reasons **Option 6:** Security reasons
			Question 9.4: What did your household do in response to this [SHOCK] to try to regain your former welfare level? **Option 8:** Household members migrated
MWI_2010_IHS-III_v01_M	Third Integrated Household Survey 2010-2011	Malawi	**Question B13:** What was the main reason that [NAME] moved here? **Option 11:** Looking for land to farm
			Question U04: What did your household do in response to this [SHOCK] to try to regain your former welfare level? **Option 8:** Household members migrated
MWI_2010-2013_IHPS_v01_M	Integrated Household Panel Survey 2010-2013 (Short-Term Panel, 204 EAs)	Malawi	**Question B13:** What was the main reason that [NAME] moved here? **Option 11:** Looking for land to farm
			Question U04: What did your household do in response to this [SHOCK] to try to regain your former welfare level? **Option 8:** Household members migrated
MWI_2016_IHS-IV_v04_M	Fourth Integrated Household Survey 2016-2017	Malawi	**Question B13:** What was the main reason that [NAME] moved here? **Option 11:** Looking for land to farm

			Question U04: What did your household do in response to this [SHOCK] to try to regain your former welfare level? **Option 8:** Household members migrated
MWI_2019_IHS-V_v04_M	Fifth Integrated Household Survey 2019-2020	Malawi	**Question B13:** What was the main reason that [NAME] moved here? **Option 11:** Looking for land to farm
			Question U04: What did your household do in response to this [SHOCK] to try to regain your former welfare level? **Option 8:** Household members migrated
MLI_2014_EACI_v03_M	Enquête Agricole de Conjoncture Intégrée 2014	Mali	**Question 11.05 (Questionnaire Part 2):** Quelle a été la stratégie adoptée par le ménage après le [CHOC] pour faire face à la situation? **Option 11:** Migration de membres du ménage
MLI_2017_EAC-I_v03_M	Enquête Agricole de Conjoncture Intégrée aux Conditions de Vie des Ménages 2017	Mali	**Question 5.05 (Questionnaire Part 2):** Quelle a été la stratégie adoptée par le ménage après le [CHOC] pour faire face à la situation? **Option 11:** Migration de membres du ménage
NER_2011_ECVMA_v01_M	National Survey on Household Living Conditions and Agriculture 2011	Niger	**Question 11.05 (Questionnaire Part 2):** Quelle a été la stratégie adoptée par le ménage après le [CHOC] pour faire face à la situation? **Option 11:** Migration d'un ou plusieurs membres du ménage
NER_2014_ECVMA-II_v02_M	National Survey on Household Living Conditions and Agriculture 2014, Wave 2 Panel Data	Niger	**Question 10.05 (Questionnaire Part 1):** Quelle a été la stratégie adoptée par le ménage après le [CHOC] pour faire face à la situation? **Option 11:** Migration d'un ou plusieurs membres du ménage

NGA_2010_GHSP-W1_v03_M	General Household Survey, Panel 2010-2011, Wave 1	Nigeria	**Question 1.33 (Post-planting questionnaire)** Why did [NAME] leave this household? **Options 4:** Left to find better land **Options 5:** Health reasons **Options 6:** Security reasons
			Questions 1.35 (Post-planting questionnaire) & 1.39 (Post-harvesting questionnaire): What was the most important reason [NAME] migrated abroad? **Options 2:** To find better or more land **Options 3:** Health **Options 8:** Security
			Question 15A.4 (Post-harvesting questionnaire): Rank the 3 most significant shocks you have experienced (1) most severe; (2) second most severe; (3) third **Option 10:** Members of the household migrated for work
NGA_2012_GHSP-W2_v02_M	General Household Survey, Panel 2012-2013, Wave 2	Nigeria	**Questions 1.29 (Post-planting questionnaire) & 1.28 (Post-harvesting questionnaire)** Why did [NAME] leave this household? **Options 4:** Left to find better land **Options 5:** Health reasons **Options 6:** Security reasons
			Questions 1.35 (Post-planting questionnaire) & 1.34 (Post-harvesting questionnaire): What was the most important reason [NAME] migrated abroad? **Options 2:** To find better or more land **Options 3:** Health **Options 8:** Security

			Question 15A.5 (Post-harvesting questionnaire): What was the most important consequence of the most recent [SHOCK]? **Option 10:** Members of the household migrated for work
NGA_2015_GHSP-W3_v02_M	General Household Survey, Panel 2015-2016, Wave 3	Nigeria	**Questions 1.29 (Post-planting questionnaire) & 1.28 (Post-harvesting questionnaire)** Why did [NAME] leave this household? **Options 4:** Left to find better land **Options 5:** Health reasons **Options 6:** Security reasons
			Question 1.34 (Post-harvesting questionnaire): What was the most important reason [NAME] migrated abroad? **Options 2:** To find better or more land **Options 3:** Health **Options 8:** Security
			Question 15A.5 (Post-harvesting questionnaire): What was the most important consequence of the most recent [SHOCK]? **Option 10:** Members of the household migrated for work
NGA_2018_GHSP-W4_v02_M	General Household Survey, Panel 2018-2019, Wave 4	Nigeria	**Questions 1.29 (Post-planting questionnaire) & 1.28 (Post-harvesting questionnaire)** Why did [NAME] leave this household? **Options 4:** Left to find better land **Options 5:** Health reasons **Options 6:** Security reasons
			Question 15A.7 (Post-harvesting questionnaire): How did your household cope with the most recent [SHOCK]? **Option 10:** Members of the household migrated for work
TZA_2012_NPS-R3_v01_M	National Panel Survey 2012-2013, Wave 3	Tanzania	**Question R.6:** What did your household do in response to this [SHOCK] to try to regain your former welfare level?

			Option 8: Household members migrated
UGA_2009_UNHS_v01_M	National Household Survey 2009-2010	Uganda	**Question 16.4:** How did your household cope with this [SHOCK]? Option 7: Household member(s) migrated
			Question 3.18: What was the main reason for moving to the current place of residence? **Option 3:** Drought, flood or other weather related condition
UGA_2010_UNPS_v01_M	National Panel Survey 2010-2011	Uganda	**Question 16.4:** How did your household cope with this [SHOCK]? **Option 7:** Household member(s) migrated
			Question 3.18: What was the main reason for moving to the current place of residence? **Option 3:** Drought, flood or other weather related condition
UGA_2011_UNPS_v01_M	National Panel Survey 2011-2012	Uganda	**Question 16.4:** How did your household cope with this [SHOCK]? **Option 7:** Household member(s) migrated
			Question 3.18: What was the main reason for moving to the current place of residence? **Option 3:** Drought, flood or other weather related condition
UGA_2013_UNPS_v01_M	National Panel Survey 2013-2014	Uganda	**Question 16.4:** How did your household cope with this [SHOCK]? **Option 7:** Household member(s) migrated
			Question 3.18: What was the main reason for moving to the current place of residence? **Option 3:** Drought, flood or other weather related condition

UGA_2015_UNPS_v01_M	National Panel Survey 2015-2016	Uganda	**Question 16.4:** How did your household cope with this [SHOCK]? **Option 7:** Household member(s) migrated
			Question 3.18: What was the main reason for moving to the current place of residence? **Option 3:** Drought, flood or other weather related condition
UGA_2018_UNPS_v01_M	National Panel Survey 2018-2019	Uganda	**Question 16.4:** How did your household cope with this [SHOCK]? **Option 7:** Household member(s) migrated
UGA_2019_UNPS_v01_M	National Panel Survey 2019-2020	Uganda	**Question 16.4:** How did your household cope with this [SHOCK]? **Option 7:** Household member(s) migrated