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Temporary Migration Response to Rainy Season Conditions in Senegal: New Evidence using Mobile Phone Data

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In the Sahel, rural livelihoods dominated by agropastoral activities are both highly dependent on rainfall and exposed to climatic shocks. Households thus face significant year-to-year volatility in production and income, to which they respond by adopting consumption smoothing strategies, depleting buffer stocks, or relying on risk-sharing networks. Alternatively, they may choose to supply labour in different markets by engaging in temporary migration strategies, either ex ante to diversify income sources or ex post in response to adverse shocks. However, these forms of adaptation have been relatively understudied, mainly due to the scarcity of data on such short-term movements. In this policy brief, we report on recent work using mobile phone data to investigate temporary migration responses to rainy season conditions in the context of Senegal.

Phone based estimates of temporary migration

Previous research on migration has primarily used survey data and focused on long-term movements. This includes studies investigating the impact of climate change on urbanization dynamics (Cattaneo and Peri 2016; Barrios et al. 2006) or the impact of climate variability and climatic events on long-term migration (Mastrorillo et al. 2016; Defrance et al. 2023). However, finer mobility patterns such as seasonal, circular, or temporary migrations clearly outweigh longer-term movements (Coffey et al. 2015; Bryan et al. 2014), but are much more difficult to capture with traditional survey instruments. In this context, mobile phone data have emerged as a promising alternative for studying more subtle human movements, especially in developing contexts (Blumenstock 2012; Demissie et al. 2019).

In our study, we use Call Detail Records (CDR), which capture the movements of millions of individuals over a three-year period.[1] The universe of phone users is obviously a non-random subset of the population. However, selection biases are found to be limited, and the data plausibly represent a large fraction of the adult population, covering the entire

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[1] *CDR are mobile phone metadata that contain information about phone calls and text messages made and received by subscribers. Each SIM card is assigned a unique identifier, and billing records provide the timestamp and approximate location associated with each phone transaction, making it possible to reconstruct trajectories through space and time.*

country, from the remotest rural areas to the urban core. Migration events are detected in the CDR trajectories using a clustering method, and user-level migration trajectories are aggregated to provide spatially detailed measures of temporary migration (see Blanchard and Rubrichi 2024).

CDR-based estimates of temporary migration offer several benefits

Mobile phone data have a number of important advantages over more traditional survey-based instruments. First, migration measures derived from mobile phone traces are not subject to recall bias. The recall bias is a well-known problem in migration studies using survey data, and is likely to be exacerbated in the case of short-term events. Second, they make it possible to measure short-term mobility patterns at the national level and over several years at a fraction of the cost of a data collection effort that would provide an equivalent level of information. In sub-Saharan Africa, where lack of resources and capacity limits the production of reliable data on internal temporary migration dynamics, mobile phone data represent an invaluable source of information.

Temporary migration patterns in Senegal

The mobile phone data we use provide novel insights into the size, timing, duration, and direction of temporary migration flows in Senegal at an unprecedented level of spatial and temporal resolution. Several key findings emerge from our analysis.

First, the data show that temporary migration is very common in Senegal. We estimate that 4.3 million migration events of at least 20 days – our benchmark definition of a temporary migration episode – occurred in 2013. Of course, this number decreases with the duration threshold considered: 2.9 million events of at least 30 days, 1.2 million events of at least 30 days and 0.5 million events of at least 90 days. Taking into account that multiple events may refer to the same person, 33% of the adult population – about 2.6 million people – were involved in one or more migrations of at least 20 days in 2013. By comparison, the rate of long-term migration in the same year was estimated to be around 2%, meaning that the short-term movements we observe in the data are arguably substantial.[2]

Short-term movements outnumber long-term census-based migration by a factor of 15

Second, the median and mean duration of temporary migration episodes are estimated to be 38 and 50 days, respectively. Overall, the variation in the observed duration of temporary moves remains relatively modest, with over 70% of migration episodes lasting for less than 2 months.

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[2] *Authors' calculation based on a 10% extract from the 2013 census (Minnesota Population Center, 2020).*

Third, migration flows are largely dispersed throughout the country, creating an extensive network of connections, both within and between rural and urban areas (Figure 1). Large cities such as Dakar, Touba, Ziguinchor, Thiès or Kaolack send large numbers of migrants in absolute terms, but more importantly, they are poles of attraction for temporary migrants from all over the country. In 2013, Dakar alone attracted 25% of the total flow. On the other hand, a clear majority of migration flows originate from rural areas, accounting for 65% of the total outflow. Nevertheless, a significant fraction of rural outflows is directed to other rural areas. Rural-to-rural movements account for one third of the total flow and these movements are primarily short-distance.[3]

Finally, the temporal distribution of short-term movements shows clear seasonal patterns (Figure 2). In all three years, a steep increase in the stock of migrants is consistently observed, starting in June and peaking in August-September. The magnitude of this increase is striking, with the number of migrants more than doubling between the first half of June and the second half of September in 2013. This increase is largely driven by rural-urban migration. More broadly, the systematic reallocation of labour from the rural to the urban sector during the rainy season (June-October) suggests the existence of income diversification strategies. This finding contradicts the common perception that temporary migration is limited to rural-urban

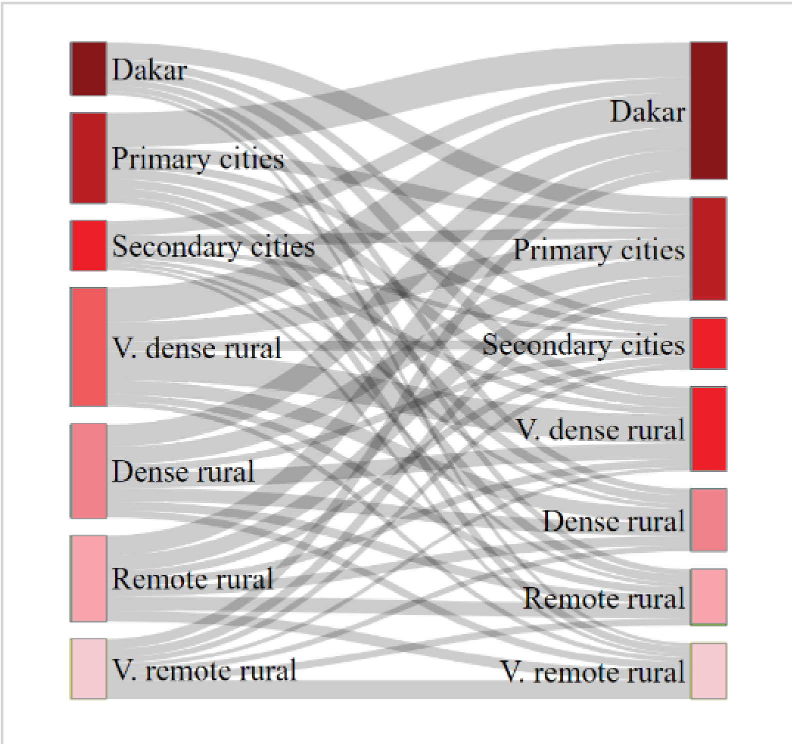


Figure 1: Migration flows between rural and urban zones in 2013

[3] *The median distance traveled by rural residents to other rural locations is 39km. In contrast, the median distance traveled to migrate to urban locations is 214km. Urban dwellers do not show such differences and travel comparable median distances to migrate to rural and urban locations – 172km and 178 km, respectively.*

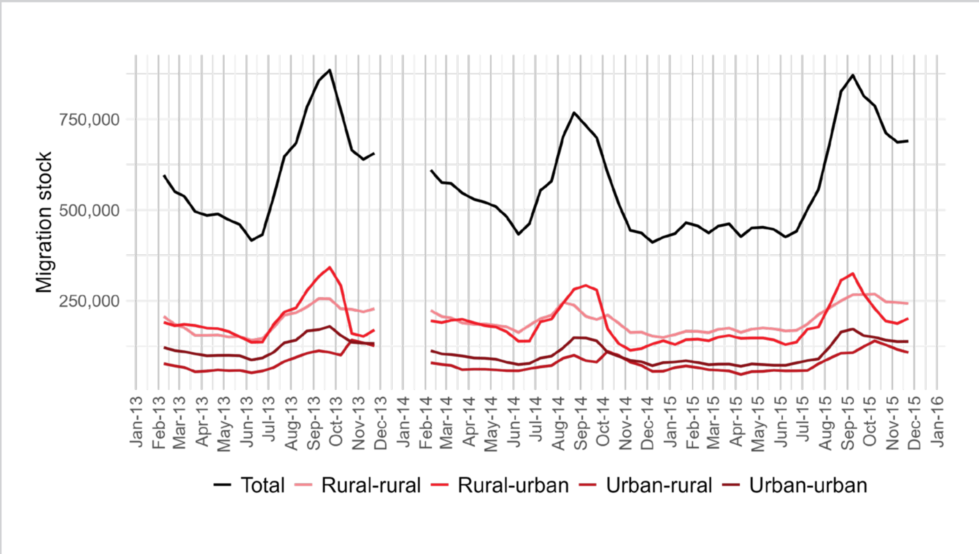


Figure 2: Stock of temporary migrants in the period 2013-2015 by origin-destination zone

movements during the off-season, but confirms observations made at a very local level in a recent study in Senegal (Delaunay, et al., 2016). Reassuringly, we also find significant rural-to-rural movements during the rainy season, coinciding with the intensification of agricultural activities. The stock of rural migrants tends to remain high even after October, plausibly reflecting harvest activities.

The impact of rainy season conditions on temporary migration

Our mobile phone data reveal a certain degree of regularity in the temporary migration patterns that have been observed over a number of years. However, these patterns may be ambiguously influenced by rainy season conditions. While poorer rainfall conditions at an individual's home location could act as a push factor (Findley 1994; Henry et al. 2004), they also exacerbate liquidity constraints and reduce the ability to meet the costs of migration. Furthermore, conditions at potential destinations may also influence migration decisions, as poorer rainfall conditions plausibly reduce the attractiveness of these destinations. To quantify these effects, we combine our detailed estimates of origin-by-destination temporary migration derived from mobile phone data with satellite-based local measures of rainfall over the period 2013-2015. We then use regression methods to estimate the impact of rainy season quality at origin and destination on the number of movers. We use half-month measures of migration, allowing us to accurately capture the timing of these effects over the agricultural year.[4]

Our results suggest that, all else equal, drier conditions (i.e., less rainfall) at a rural origin during the rainy season reduce migration to both rural and urban destinations during the harvest season, when temporary migration peaks, and increase migration to other rural areas during the off-season, at the trough of the migration curve (Figure 3). The negative effect observed

[4] *An agricultural year is defined here as the sequence of a rainy season (June to October of a given year), followed by the harvest season (November-December) and ending with the off-season (January to May of the next year).*

during the harvest season is amplified in impoverished households and communities (as discussed below), aligning with the credit-constraint mechanism. Conversely, the positive effect observed in the subsequent off-season is consistent with a risk-coping strategy. Interestingly, we find no statistical evidence for the existence of an effect on off-season rural-to-urban migration. In quantitative terms, a 10% decrease in rainfall is associated with a 3-6% (3%) decrease in rural (urban) migration during the harvest season and an increase of up to 15-17% during the off-season. Although the relative response is greater in the off-season, it applies to a smaller number of migrants, as shown in Figure 2. We also estimate these effects for urban origins, and the results overall reflect the fact that urban dwellers are much less sensitive to the quality of the rainy season.

Reduced rainfall results in significantly less migration during the harvest season

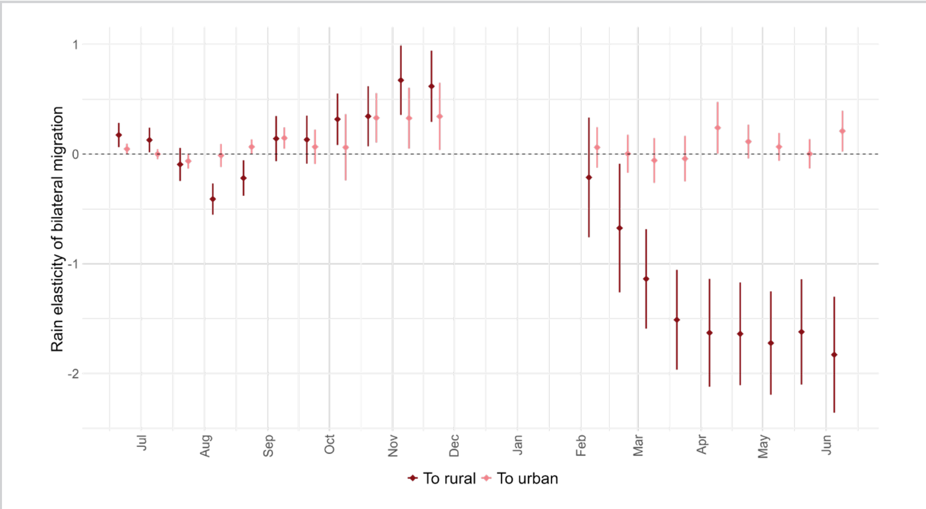


Figure 3: Effect of participations at a rural origin on the bilateral number of temporary migrants

*Note: Vertical bars represent 95% confidence intervals based on two-way clustered standard errors at the (origin*half-month) and (destination*half-month) levels.*

On the other hand, the amount of rainfall in rural destinations tends to have a positive effect on the migration to these areas. In other words, higher rainfall makes rural destinations relatively more attractive to temporary migrants, consistent with the notion that it increases productivity within the agropastoral sector. This effect is particularly pronounced for off-season migration from other rural areas. On average, a 10% increase in rainfall during the rainy season at a rural destination leads to an increase of up to 15% in the migration stock from a rural location to that destination.

To further investigate the heterogeneity of these effects, we use remote sensing information along with survey and census data to obtain local estimates of the socio-economic characteristics of local populations. We then estimate the magnitude of bilateral migration responses to conditions at origin and destination as a function of these characteristics.

Our main findings suggest that the off-season, rural-to-rural response to origin conditions is relatively stronger in poorer locations with a more pronounced livestock sector. Households in poorer areas often have limited capacity for consumption smoothing (e.g., limited access to credit, savings, or buffer stocks) and fewer employment opportunities in the local labour market. Our results suggest that such circumstances lead to reduced resilience and increased reliance on temporary migration as a risk coping mechanism. Moreover, pastoral households are an inherently mobile population, and the results suggest that, other things being equal, poorer conditions increase the migration of herders, forcing them to search for water and fodder resources away from their usual place of residence.

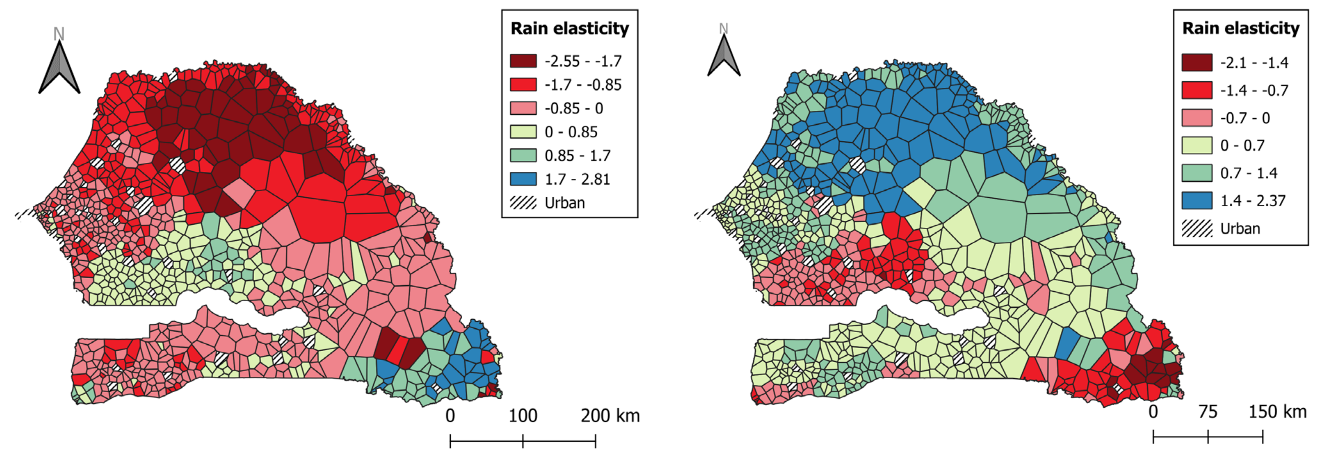
We also find that locations characterised by greater cultivation of drought-resistant crops, such as sorghum, exhibit an off-season rural-to-rural migration response that is less sensitive to conditions at origin. This trend is also observed in peanut-producing areas, consistent with the remarkable resilience of peanut production in 2014 despite the significant rainfall deficits observed. Interestingly, the results also show that during the harvest period, the attractiveness of rural destinations characterised by higher sorghum production is less sensitive to rainfall conditions.

By incorporating a combination of such factors into our model, we can assess the overall sensitivity of the out-migration rate to local rainfall conditions for each individual location. The map in Figure 4.a shows the estimated sensitivity of rural-to-rural off-season migration to rainfall for each location. Consistent with the results in Figure 3, most locations exhibit negative responses; worse rainfall conditions at origin increase the propensity to migrate. The map clearly shows that this "push" effect is particularly pronounced in the northern half of the country, a region that is relatively poorer and dominated by pastoral activities.

Similarly, we estimate the average sensitivity of the out-migration rate to a given location with respect to the conditions at that (destination) location. The results are shown in Figure 4.b and the patterns are broadly consistent with those in Figure 4.a, with effects in the opposite direction. In short, areas with larger push effects also coincide with destinations whose attractiveness is relatively more affected by poorer rainfall conditions.

Our regression results allow us to quantify how relative changes in rainfall affect a bilateral temporary migration stock. Focusing on rural-to-rural movements during the off-season, we show that conditions at origin and destination act in opposite directions and that the magnitude of these effects varies across space. Armed with these insights, we therefore inquire about the aggregate impact of specific rainy season condition scenarios on temporary migration. For example, we use our regression model to compare aggregate temporary migration stocks during the 2014-2015 agricultural year with estimated migration outcomes for a "neutral" scenario in which all locations receive their historical average rainfall.

Migration responses
are more pronounced
in poorer locations



4.a. Sensitivity of rural-rural migration to origin-rainfall, off season

4.b. Sensitivity of rural-rural migration to destination rainfall, off season

Figure 4: Sensitivity of off-season migration to rainy season conditions at origin and destination

Note: For each location, the off-season elasticity corresponds to the average elasticity estimated by half-month over the March-May period.

In the core of the 2014-2015 off-season, we find that the average rural-rural temporary migration stock is 5 percent higher than in the reference scenario, equivalent to an additional 8,000 migrants. As expected, this difference is larger for subgroups of locations that show greater sensitivity to conditions at origin. Both the poorest 25% of locations and the top 25% with the highest livestock per capita show a difference of about 13%. Conversely, the estimated rural-urban, urban-rural and urban-urban migration stocks are all observed to be smaller than in the reference scenario.

A similar comparison for the harvest period yields an average difference of -15% in the rural-rural temporary migration stock between the 2014 and reference scenarios, equivalent to a decrease of 34,000 migrants. We find similar results for rural-urban, urban-rural and urban-urban movements, with negative differences in the range of -15% to -17%. This translates into an average reduction of almost 100,000 migrants in the temporary migration stock compared to the reference scenario.

In summary, these results suggest that the drier conditions of the 2014 rainy season have undermined both the capacity to migrate and the expected return to migration, leading primarily to a net reduction in temporary migration, which is particularly pronounced during the harvest season.

Conclusion

Short-term internal migration is an integral part of economic decision-making in developing countries, yet its accurate measurement remains a significant challenge. Our research highlights the great promise of mobile phone data in addressing this issue, and provides new insights into temporary migration patterns in Senegal. We exploit the unique granularity of phone-based migration estimates to examine the response of temporary migration to rainy season conditions. The dataset allows us to precisely examine the impact of rainfall conditions at both origin and destination on the decision to migrate between any pair of locations. It also allows us to examine how these effects vary spatially and across different seasons.

Overall, our results highlight the complex nature of temporary migration responses to rainy season conditions. While drier conditions significantly reduce migration during the harvest season, they induce some degree of spatial rural-rural reallocation during the off-season. Overall, the migration response appears to be relatively modest, especially during the off-season. In particular, the data strongly suggest that, contrary to prevailing narratives, there is no substantial off-season rural-urban migration response to an adverse shock, with individuals temporarily seeking employment in the urban sector in times of hardship.

Taking our investigation a bit further through a quantification exercise based on a comparison of temporary migration stocks in the 2014 agricultural year and in a scenario calibrated to "normal" circumstances, we find that widespread drier conditions (as experienced in the 2014 agricultural year) lead to a significant reduction in the total volume of short-term movements, and are most pronounced during harvest.

These findings have important implications. First, they call for more research to understand how such a reduction in the volume of temporary migration translates into income and consumption losses in localities where mobility is critical for livelihoods and resilience. Second, they raise questions about the timing of any response. Seasonal variability in rural well-being implies that interventions to support production and consumption also need to be carefully timed. Food aid, for example, is typically delivered in the off-season, when granaries are depleted and food market prices are high. But because the effects of poor conditions on temporary migration are felt early, support for smallholder farmers may well be needed earlier. Finally, our findings on how rainfall conditions, ecosystems, livelihoods, and mobility interact at local scales reveal heterogeneity in the sensitivity of temporary migration to rainfall conditions. This provides some guidance for the geographic targeting of policies or programmes, as well as for identifying the most appropriate response options.

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