“Urban Exodus” During COVID-19 in Mexico? Using Digital Data to Analyze Medium-Term Pandemic Impacts on Internal Population Movements

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Abstract: Previous work documented a decline of internal population movements and an increase in outflows from large cities to less densely populated areas during COVID-19 in Global North countries. However, the impact of the pandemic on levels and patterns of human mobility across the rural-urban hierarchy in the Global South is yet to be established. Lack of data with temporal and spatial granularity has prevented us from assessing this research gap. Drawing on location data of Facebook users, we analyse how the intensity and patterns of long-distance movements (>100 Km) were affected during April 2020-May 2022 across different population density categories in Mexico. We find a decline of 40% in the total number of long-distance movements during April-December 2020, and a systematic decrease of outflows and inflows across the rural-urban hierarchy. Unlike in the Global North, outflows from large cities did not increase. The largest drop of outflows and inflows occurred in large cities, declining by 50%. Only specific flows increased during COVID-19, as those from large cities to certain towns, and intra-rural movements. The intensity and patterns of internal population movements across the rural-urban hierarchy have progressively returned to pre-pandemic levels during 2021 and 2022, as has occurred in Global North countries. However, the recovery has been slower in the large Mexican cities.

Keywords: Human mobility, rural-urban hierarchy, COVID-19, Facebook data, Latin America, Global South.

1. Introduction

Nowadays, together with international migration, internal population movements have become a key component of population change, shaping patterns of human settlement within national boundaries (Bell et al. 2015). Human mobility underpins the functioning of the economy by bringing population, labour force and skills to the locations where they are needed (Van Ham et al. 2001). Thus, understanding changes on intensities and patterns of internal population movements is of utmost importance for researchers and policy makers.

The COVID-19 pandemic reduced internal population movements worldwide (Nouvellet et al. 2021; González-Leonardo et al. 2022a and 22022b; Rowe et al. 2023b). Declines were documented across Global North countries during 2020, such as the United States (Ramani and Bloom 2021), different European states, Japan and Australia (Rowe et al. 2023b). Drops ranged from 2.5% in Spain to 8.5% in Australia. Declines were also recorded in some countries across Latin America and the Caribbean, from 3% in Venezuela to 19% in Bolivia (Aromí et al. 2023). Reductions of internal population movements were attributed to involuntary immobility due to lockdowns and mobility restrictions, and also to an increase in teleworking and a loss of labour market dynamism (Bernard and Perales 2023).

The COVID-19 pandemic also altered patterns of internal population movements across the rural-urban hierarchy in the Global North (Rowe et al. 2023b). An increase of movements from large cities to less densely populated areas, unusual population growth in the former, and a decline of urbanization flows were documented in the United States (Ramani and Bloom 2021), United Kingdom (Rowe et al. 2023a; Wang et al. 2022), Spain (González-Leonardo et al. 2022; González-Leonardo et al. 2022a and 2022b), Germany (Stawarz et al. 2022), Sweden (Vogiazides and Kawalerowicz 2022), Norway (Tønnessen 2021), Australia (Perales and Bernard 2022), and Japan (Fielding and Ishikawa 2021; Kotsubo and Nakaya 2022). Tourist towns with a high concentration of second homes were popular destinations, suggesting that wealthy individuals played a key role in movements away from large cities during the pandemic (González-Leonardo et al. 2022a and 2022b; Vogiazides and Kawalerowicz 2022; Rowe et al. 2023b).

Evidence from small surveys in two developing countries, India (Irudaya-Rajan et al. 2020) and South Africa (Ginsburg et al. 2022), suggests that movements from large cities to towns and small cities increased in 2020. These surveys also indicate that inflows to major cities declined and some workers may have returned to their home towns due to economic slowdown and business closures during the pandemic. Studies on the socioeconomic selectivity of internal population movements during the pandemic in the Global South point to wealthy individuals as key actors in outflows from large cities (Lucchini et al. 2023). These authors estimate that residents from wealthy neighbourhoods were 1.5 times more likely to leave cities than those from poor areas in Brazil, Colombia, Indonesia, Mexico, Philippines and South Africa. This result is consistent with data from Chile, which show an overrepresentation of high-income individuals among people leaving Santiago during COVID-19 (Elejalde et al. 2023). Wealthy individuals have the economic resources to move, are able to work remotely, and own second homes outside large cities. Low-income people lack financial resources to move. Additionally, a large share of low-income individuals has face-to-face jobs within the informal economy (ILO 2021). This type of jobs may have prevented them from moving out of large cities during COVID-19.

Alterations to human mobility trends seem to have been temporary in developed countries, where there is evidence until 2021. They were concentrated during periods of high stringency, and disappeared when restrictions were eased (Rowe et al. 2023b). The intensity and spatial patterns of human mobility were similar to those observed before the pandemic by mid-2021 in the United Kingdom (Rowe et al. 2023a; Wang et al. 2022) and by the end of 2020 in Australia (Perales and Bernard 2022). In Spain, urbanization movements recovered pre-pandemic values after the end of the national lockdown in mid-2020, although unusually high levels of counterurbanisation persisted during 2021, despite showing a decreasing trend over this year (González-Leonardo et al. 2022b).

Existing work has contributed to understanding the effect of the pandemic on internal population movements across the rural-urban hierarchy in the Global North, including findings until 2021. To date, there is some evidence on how the intensity of human mobility declined during early stages of the pandemic in Global South countries, and also on the socioeconomic selectivity of movements. However, how COVID-19 affected patterns of human mobility across the rural-urban hierarchy and the durability of potential changes are yet to be established in developing countries. Lack of consistent time-series data on population movements in developing countries has prevented us from empirically testing this research gap.

We could expect different pandemic impacts on internal population movements across the rural-urban hierarchy in the Global South than in the Global North. On the one hand, studies both in developing and developed countries suggest that wealthy individuals played a key role in outflows from large cities during the pandemic. On the other hand, the share of this population group is much lower in developing countries (Milanovic and Yitzhaki 2002). Thus, we could anticipate that movements from large cities to less densely populated areas during COVID-19 were of less importance in the Global South, since the number of potential movers was lower.

In this paper, we use location data from Facebook app users to analyse how intensities and patterns of long-distance movements (>100 km[1] in Euclidean distance) changed across the rural-urban hierarchy between April 2020 and May 2022 in Mexico. First, we explore variations in outflows and inflows in different population density categories during 2020, 2021 and 2022, compared to a baseline period of 45 days prior to the pandemic. Second, we analyse monthly changes on origin-destination flows between pairs of population density categories. Specifically, we seek to answer the following research questions: 1) How did levels and patterns of internal population movements change across the rural-urban hierarchy during COVID-19 2) Did outflows from large cities increase? 3) Did potential changes persist over the pandemic?

The rest of the paper is structured as follows: We explain the data and methods of this research. We next present the results of the study by analysing how outflows and inflows of Facebook users changed across the rural-urban hierarchy, and exploring monthly variations of origin-destination movements in different population density categories. Finally, we discuss the result and present the conclusions of this work.

2. Data and methods

2.1. Data

We use aggregated and anonymized data from the Coronavirus Disease Prevention Map-Facebook Movements During Crisis to analyse mobility patterns during the pandemic in Mexico. This dataset is provided by Meta's Data for Good initiative, a Facebook parent company. It contains information on geolocated smartphone data from Facebook app users with the location sharing option turned on.

The movement data are aggregated into three daily 8-hour time windows (i.e., 00:00-08:00, 08:00-16:00 and 16:00-00:00). The dataset includes information from April 2020 to May 2022, and a pre-pandemic baseline period of 45 days prior to March 10, 2020. The baseline values were computed using an average for each day of the week and time window over the entire baseline period, which is then used for comparisons with the same day of the week and time window of the crisis period.

Meta aggregates georeferenced data into the Bing Maps Tile System developed by Microsoft. This system provides partitions of the world map in the form of square cells with

[1] We filter movements over 100Km to remove most daily mobility and commuting of Facebook users. Movements over 100Km potentially represent multi-day trips and internal migrations involving changes of residence.

different levels of resolution. Particularly, Facebook's mobility data is aggregated at Level 13 for Mexico, consisting of cells of about 6 sqkm, although the size may vary depending on the distance from the Equator (see Microsoft (n.d.) for more details on the Bing Map Tile System).

Meta produces the database of movements using the number of users who moved between Tiles, providing the origin and destination points. The origin and destination points are defined as the locations where a user spent most of the time between two consecutive time windows (e.g., 00:00-8:00 and 8:00-16:00). The database contains the counts of movements between two spatial units during the crisis period and the pre-pandemic baseline period. Facebook also includes the distance from origin to destination points.

Facebook removes user characteristics, aggregates the data and applies various techniques to ensure data confidentiality. They remove counts of less than 10 users. This technique may cause underrepresentation of some movements to and from units with few Facebook users, usually sparsely populated areas. Other techniques applied by Facebook are: adding a small random count of users (Random Noise); and computing a weighted average with neighbouring units to produce a spatial smoothing (see Maas et al. (2019) for more details on the database).

As a secondary source, we use the WorldPop population database to determine different categories of population density across the rural-urban hierarchy. This database contains population estimates in 1 sqkm grids (see https://www.worldpop.org/methods/ for more details on the WorldPop data). We aggregate the population estimates according to the Bing Maps Tile System Level 13 to match the WorldPop data to the spatial units in the movement database. We also use the Stringency Index from the COVID-19 Government Response Tracker repository to understand mobility patterns according to different stages of the pandemic. The original data contains daily information, which we group into months using averages. The index ranges from 0 to 100, the lowest and highest stringency levels, respectively (see Hale et al. (2021) for more details on the Stringency Index).

2.2. Methods

To analyse changes in long-distance movements across the rural-urban hierarchy during the pandemic, we first classify the working spatial units into multiple population density categories. To do so, we apply a spatial join to aggregate WorldPop population data into the Level 13 of the Bing Maps Tile System, so that it matches the level of aggregation of Facebook movement data. Next, we calculate the population density of each Tile and produce 10 categories of population density using Jenks natural breaks, where 1 and 2 are the lowest-density categories, mainly rural areas, and 10 is the highest-density category, present only in Mexico City. Categories 8 and 9 comprise other large cities in Mexico, such as Monterrey or Guadalajara. Categories 5, 6 and 7 correspond to medium-sized cities, such as Tijuana, Culiacán, Ciudad Juárez, Cancún or Puerto Vallarta. Small cities, such as Colima, Campeche or Ciudad Valles, are included in population density categories 3 and 4.

In order to remove daily mobility and commuting, we select long-distance movements (>100 Km in Euclidean distance) from the Facebook database. These movements potentially represent multi-day trips and internal migrations involving changes of residence. We calculate percentage changes in outflows and inflows for each Tile in 2020 (from April), 2021, and 2022 (until May), compared to the pre-pandemic baseline period (the 45 days prior to March 10, 2020). We combine box and violin plots to represent the median and the distribution of percentage changes in outflows and inflows of Tiles within each population density category.

Finally, to get a more comprehensive view of mobility patterns across the rural-urban hierarchy during the pandemic, we analyse the monthly origin-destination flows between pairs of different population density categories. To do so, we use an origin-destination matrix and calculate the percentage change for each flow and month, compared to the baseline period. We plot the results using a multiplot (facet grid) line graph, which shows the origin-destination matrix of movements between population density categories. We smoothed monthly data using the loess method.

3. Results

In this section, we analyse how the intensity and patterns of internal population movements changed across the rural-urban hierarchy in Mexico during the COVID-19 pandemic. Figure 2 shows the median and distribution of percentage changes in long distance outflows and inflows of Facebook users in 2020 (from April), 2021 and 2022 (until May), compared to the pre-pandemic baseline period, in spatial units within 10 population density categories. In the X-axis, the category 1 represents the lowest density and the category 10 the highest density. In the Y-axis, values below 0 indicate that outflows or inflows were lower during the pandemic, and values above 0 mean higher intensities of mobility.

Results show that the total number of movements among Facebook user declined by 40% during 2020. Figure 2 displays a consistent drop of outflows across all categories of population density and a positive gradient of decline according to population density. That is, reductions in internal population movements during 2020 were greater in the categories with the highest population density (10 and 9), where outbounds declined by 51% and 49%, respectively, according to the median value. These categories include large cities, such as Mexico City, Monterrey and Guadalajara. Figure 2 also reveals that outflows decreased by about 45% in medium cities (categories 5, 6 and 7) and by 35-40% in small cities (categories 3 and 4) and towns (category 2). Exits from sparely populated rural areas (category 1), however, did not display significant variation compared to pre-pandemic levels.

We identify a progressive recovery in outflows over 2021 and 2022. Once again, levels of recovery showed a gradient according to population density. Outflows from the most populated areas (categories 9 and 10) were still 19% and 25% lower in 2022, respectively. Medium cities (categories 5-8) registered values about 15% lower, small cities (categories 3 and 4) around 10%, and rural areas (categories 1 and 2) displayed similar outflows than those observed before COVID-19.

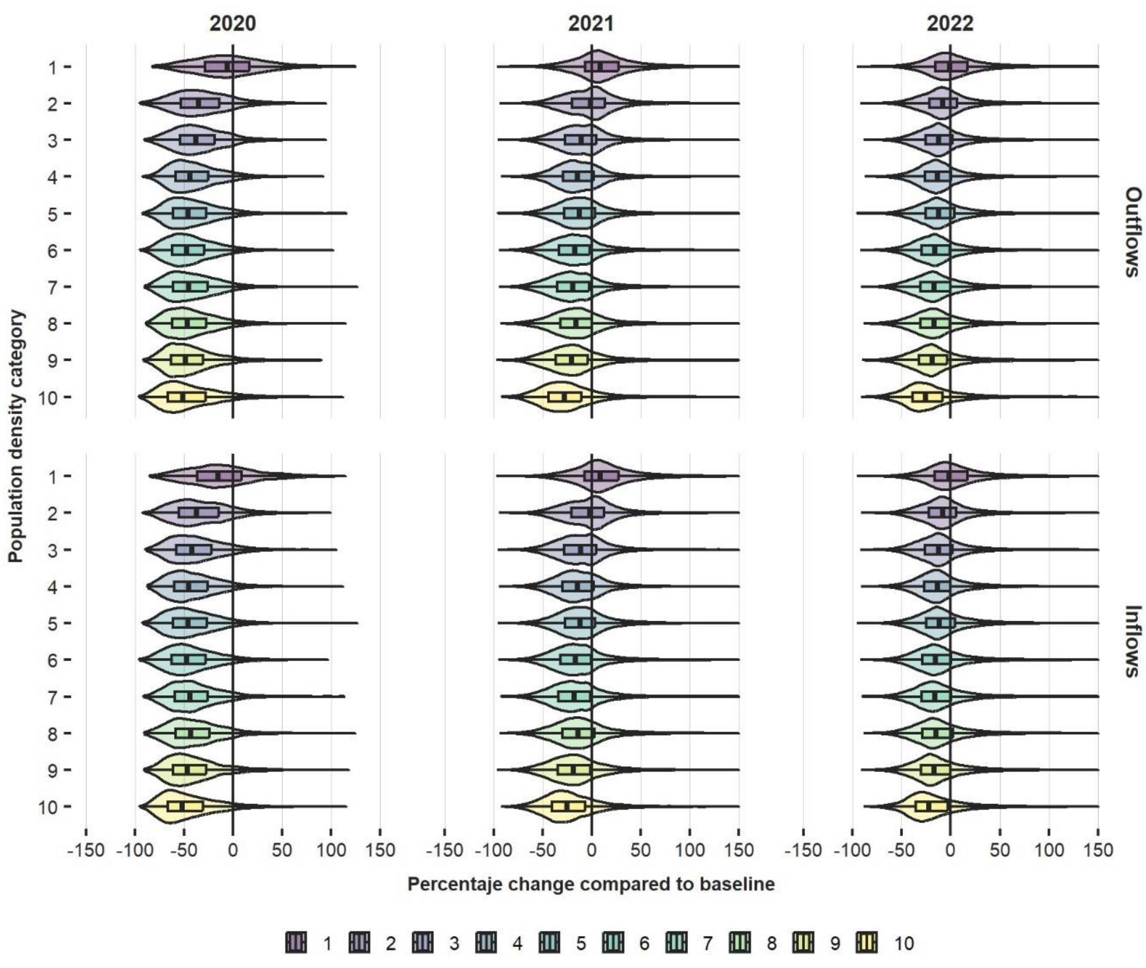

Figure 1. Percent changes in outflows and inflows (>100 km) of Facebook users by population density categories in 2020 (from April), 2021, and 2022 (until May), compared to the pre-pandemic baseline period (the 45 days prior to March 10, 2020)

Inflows show almost identical patterns to outflows. Overall, the findings indicate that there was not an "urban exodus" in Mexico during the pandemic, but a decline in long-distance movement across the country, except in sparely populated rural areas. Large cities were most affected by drops of internal population movements, with outflows and inflows halving in 2020. Although mobility levels progressively recovered to those observed before the pandemic, the most populated areas registered a slower recovery and significant lower values still in 2022.

Next, we explore how the pandemic impacted monthly origin-destination flows of Facebook users across the rural-urban hierarchy. Figure 3 shows the percentage change of movements between pairs of population density categories from April 2020 to May 2022, compared to the pre-pandemic baseline period. We display results in a multiplot graph representing the migration matrix between the different population density categories (i.e., origins in rows-the left Y-axis, and destinations in columns-the top X-axis). The categories are ordered from lowest to highest population density (0-10). In the right Y-axis, values below 0 mean that movements from population density category X to category Y are lower than before COVID-19, while figures above 0 indicate a higher number of movements. The bottom X-axis represents the variable time. In order to link variations on population movements during the pandemic to levels of stringency, such as lockdowns and mobility restrictions, we include data on the Stringency Index in the background of each plot, where darker colours indicate higher level of stringency.

Figure 3 shows a large and consistent decline in almost all movements across the rural-urban hierarchy during 2020. Declines were larger in early months of the pandemic, when the spread of the virus and stringency measures registered the highest levels. Movements between rural areas (categories 1 and 2) were an exception, with higher intensities than before COVID-19. Flows from Mexico City (category 10) to certain small cities (category 3) also displayed higher values than before the pandemic from mid-2020, and movements to sparely populated rural areas (category 1) showed almost no change.

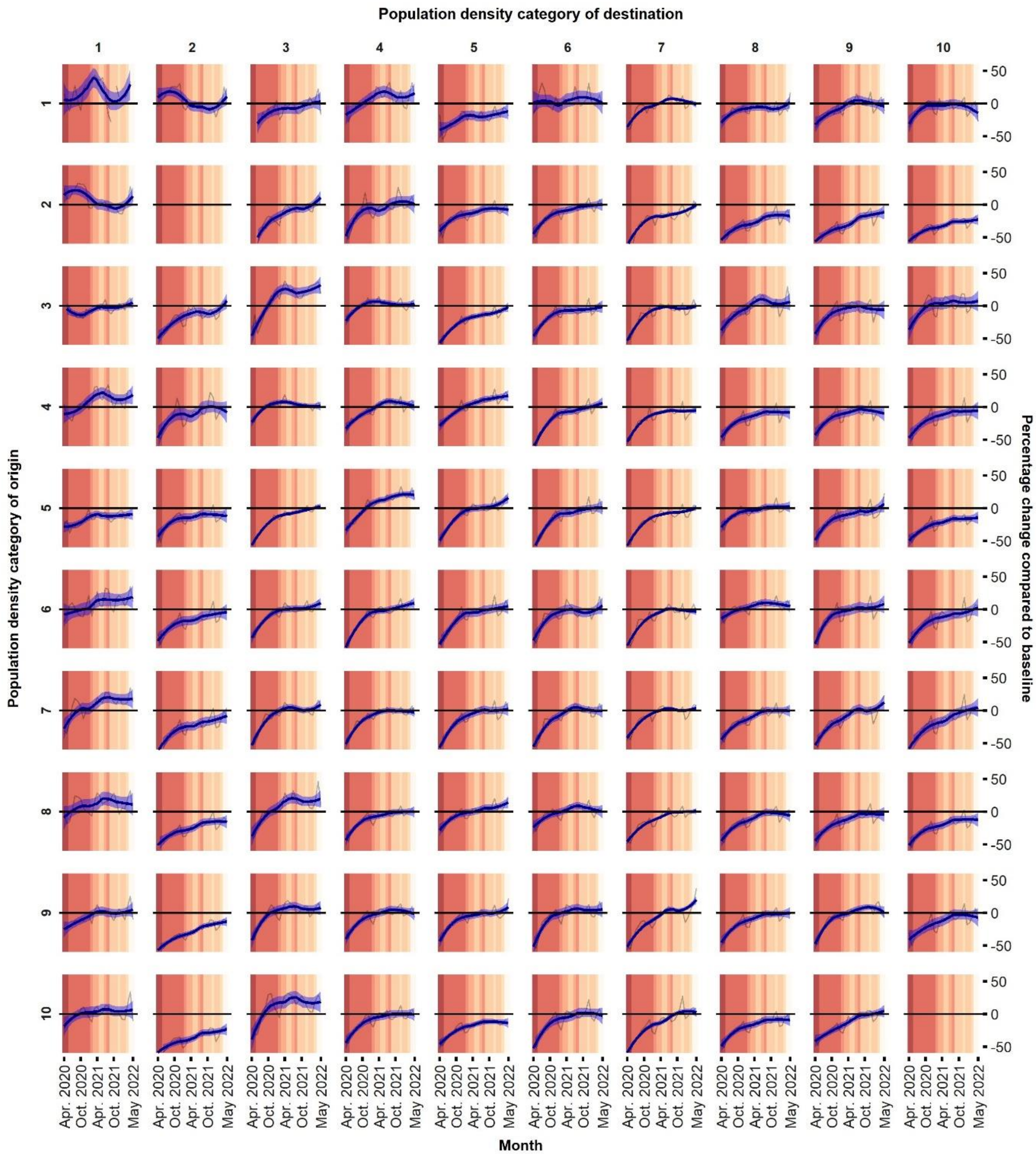

Figure 2. Percent change in movements (>100 km) of Facebook users by population density category of origin and destination from April 2020 to May 2022, compared to the pre-pandemic baseline period (the 45 days prior to March 10, 2020).

Note: Monthly values were smoothed using the loess method; 95% CIs are included in the figure; the original values are represented with a light grey line; the Stringency Index is included in the background (darker colours indicate higher levels of stringency).

During 2021 and 2022, restrictions were eased and most flows progressively recovered pre-pandemic levels. The speed of recoveries in movements to and from high density areas was, however, generally slower. Some movements from large showed significantly lower levels than before COVID-19 over 2021 and into 2022. For instance, flows from categories 8, 9 and 10 to category 2, and from category 10 to category 5. Nonetheless, unusually high levels of movements from Mexico City to certain small cities (category 3) persisted, Additionally, flows between other large cities (category 8) and category 3 also increase from 2021. The excess of inter-rural movements during of 2020 dimmed in large rural areas (category 2) in early 2021, and in small rural areas (category 1) in mid-2021. Finally, flows from large rural areas (category 2) to large cities (categories 8, 9 and 10) also registered a slower recovery and did not fully reach pre-pandemic levels in May 2022.

In summary, we confirm that there was a general decline in most movements in 2020, mainly during the period with levels of restrictions in the first months of the pandemic. However, we identify some exceptions: unusual high level of movements from Mexico City to certain small cities and greater intensities of inter-rural movements. Generally, intensities recovered to pre-pandemic levels during 2021 and 2022, but the speed of recovery in large cities was slower. Excess inter-rural mobility disappeared, but movements from large cities to certain small cities remained higher than before COVID-19, at the same time that some flows away from large cities remained lower, as those to large rural settlements.

4. Discussion and conclusions

Our results show a decline in long-distance movements of Facebook users during the COVID-19 pandemic in Mexico. The decline was concentrated in periods with high levels of stringency in 2020. These findings are consistent with the results of studies conducted in the Global North (González-Leonardo et al. 2022a and 22022b; Wang et al. 2022; Rowe et al. 2023b) and also in other Latin American countries (Aromí et al. 2023). However, our findings indicate that long-distance flows were more affected by COVID-19 than overall mobility levels. We identified a 40% decline in movements over 100km during 2020, while the drop in overall levels of human mobility in other countries ranged from 2.5 in Spain (González-Leonardo et al. 2022a) to 19% in Bolivia (Aramí et al. 2023).

Contrary to developed countries, there was no "urban exodus" in Mexico during the pandemic. Outflows of Facebook users from large cities did not increase, but decreased by 51% in April-December 2020. Only specific outbounds from large cities to certain towns registered higher values than before COVID-19. Different pandemic impacts in the Global South than in the Global North may be due to different population compositions between developed and developing countries. Studies conducted in the Global North suggested that wealthy individuals played a key role in outflows from cities during the pandemic (González-Leonardo et al. 2022a; Perales and Bernard 2022; Vogiazides and Kawalerowicz 2022), which is consistent with findings in the Global South (Elejalde et al. 2023; Lucchini et al. 2023). We should consider that the number of upper-middle class individuals in developing countries is smaller than in developed states (Milanovic and Yitzhaki,2002). Therefore, we could also expect a smaller amount of people with economic resources, second homes, and who were able to work remotely to leave large cities in the Global South during COVID-19. In addition, digital connectivity in areas with low population densities in developing countries is more limited than in developed countries, making home office difficult in remote areas across the Global South.

Our findings reveal that both outflows and inflows declined in all population density categories, from rural areas to large cities. We also identify a positive population density gradient in the intensity of the decline: the greatest declines of movements from and to large cities, and lowest in rural areas. Surprisingly, the results show an increase in inter-rural flows between mid-2020 and mid-2021. This finding may be due to the fact that the stiltedness of stringency measures in less densely populated areas was lower than in urban settlements. Our results also reveal than outflows from large cities to certain towns increased during the pandemic, potentially due to the fact that these destinations could have specific attributes, such as a high concentration of second homes, sea or natural landscapes. This would be consistent to finding in the Global North, since holiday town with these attributes were popular destination during the pandemic (González-Leonardo et al. 2022a and 2022b; Vogiazides and Kawalerowicz 2022; Rowe et al. 2023b).

Our results show a recovery in the intensity of human mobility during 2021 and 2022 in Mexico, and similar spatial patterns of movements by May 2022. As in the Global North, it seems that disruptions in the Mexican mobility system were temporary. However, we identify that some outflows and inflows in large cities displayed a slower recovery, and lower levels than those observed before COVID-19 still in 2022. The different speeds and levels of recovery raise some questions for future lines of research. Future work should confirm whether mobility intensities and patterns across the rural-urban hierarchy fully returned to normal after May 2022. They should also analyse why specific movements displayed slower recovery trends, and why certain flows between pairs of population densities showed higher levels of mobility than before the pandemic.

Concerning the limitations of this work, we must consider that digital data present biases. Not everyone has a Facebook account. There are different levels of spatial coverage, and the Facebook penetration varies by age and socioeconomic level (Gil-Clavel and Zagheni 2019; Hargittai 2020). Additionally, Facebook data only include movements of users who have the app installed on their smartphones and share their location (Maas et al., 2019). Small counts are removed in the dataset, which could lead to underrepresentation of less populated areas. Finally, we cannot isolate temporary movements from permanent changes of residence. Despite these limitations, our study provides reliable and consistent results on how the pandemic affected intensities and patterns of internal population movements in Mexico, which could be extrapolated to other countries in Latin America and the Global South. A number of countries, mostly the developing ones, do not have data with temporal and spatial granularity to analyse certain social processes. Therefore, digital data are the only option due to the lack of traditional sources.

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