Supplementary information

Human movements can inform the spatial scale of interventions against COVID-19 transmission

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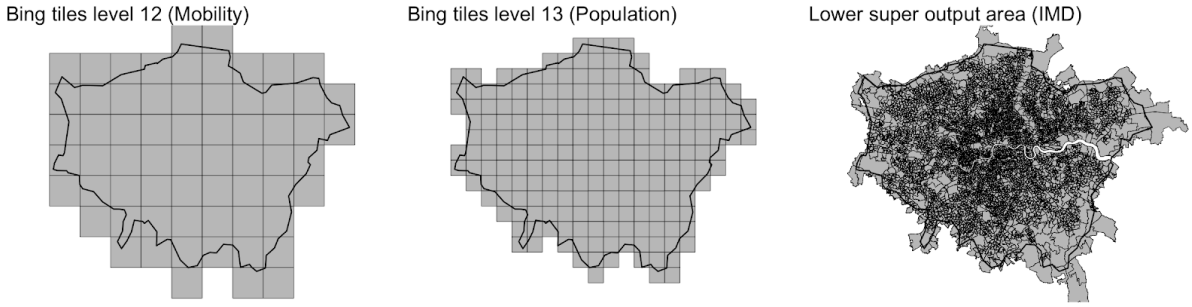
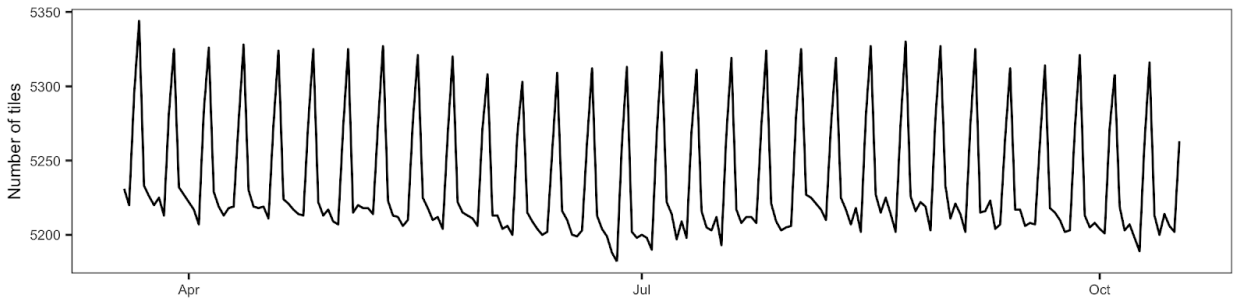
Data Representativeness

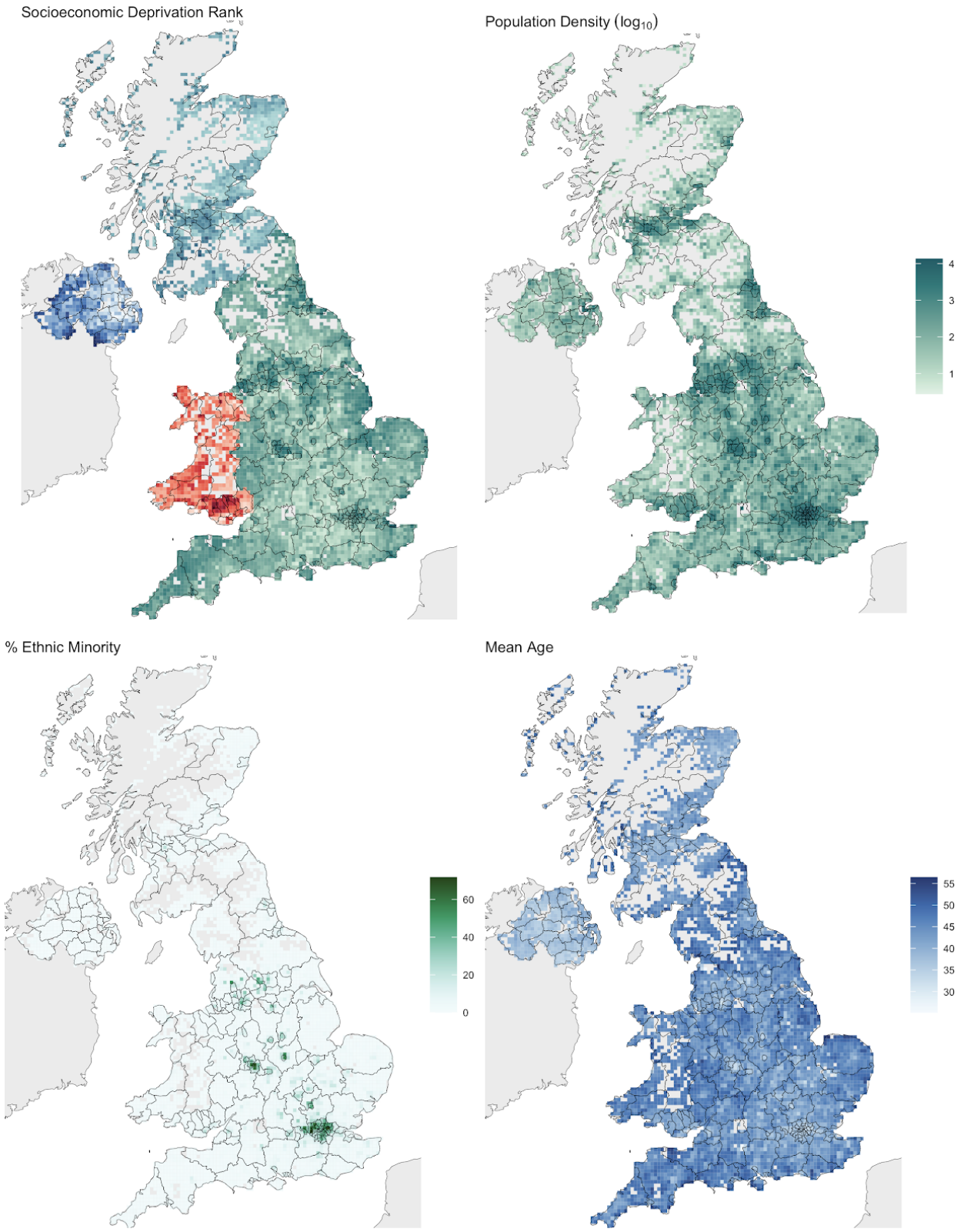
To understand the representativeness of the Facebook Movement and Population datasets, we compared the percentage of the population recorded by the Facebook movement dataset with UK census variables aggregated to the same spatial unit as the Facebook cell movement dataset. Each country of the UK (England, Scotland, Wales, Northern Ireland) was compared independently because of differences in the collection of the census variables.



Supplemental Figure 1. An overview of different geometries used in this study, intersecting London. a) Zoom level 12 tiles, b) Zoom level 13 tiles, c) Lower Super Output Areas.

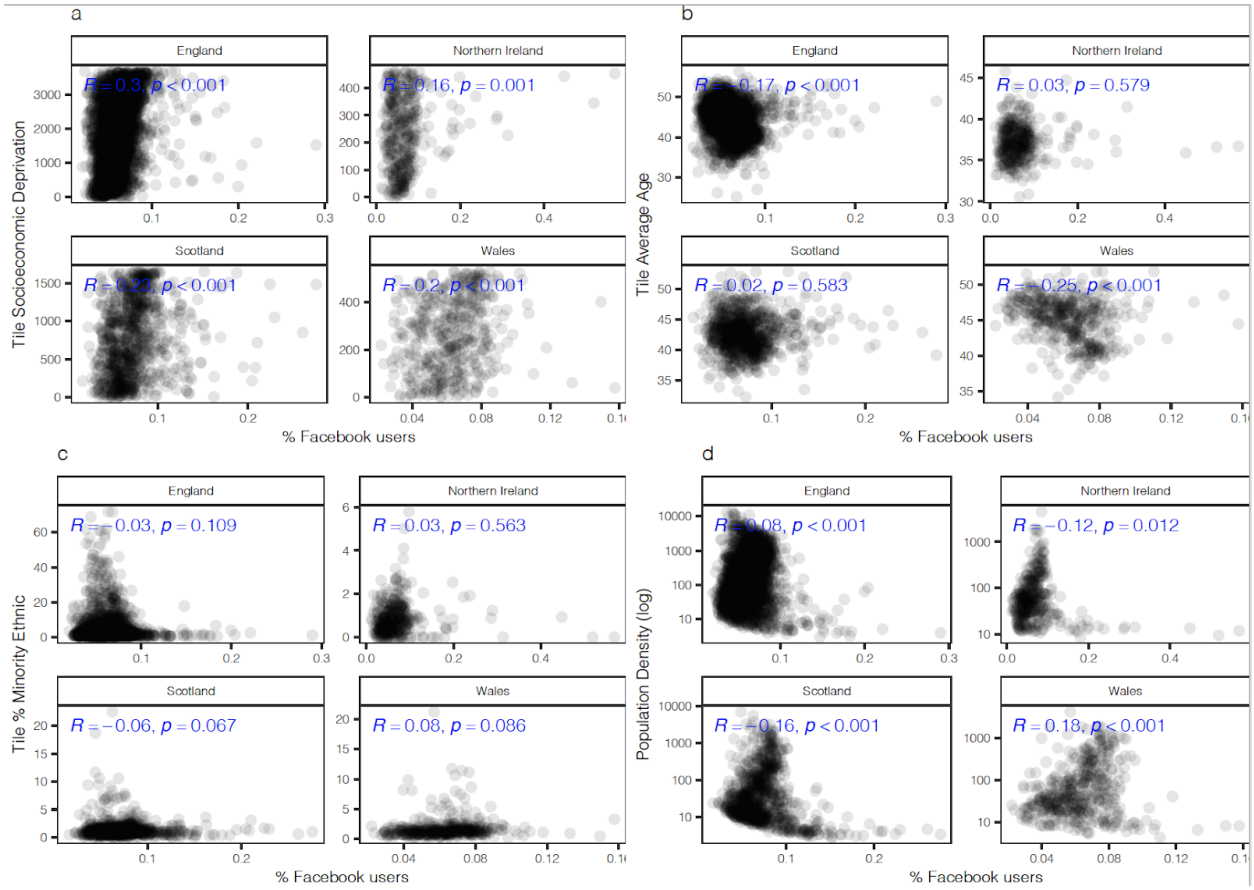


Supplemental Figure 2. The number of cells included in the dataset. Cells recording fewer than 10 persons moving between cells along any connection are censored from the dataset to preserve user privacy.

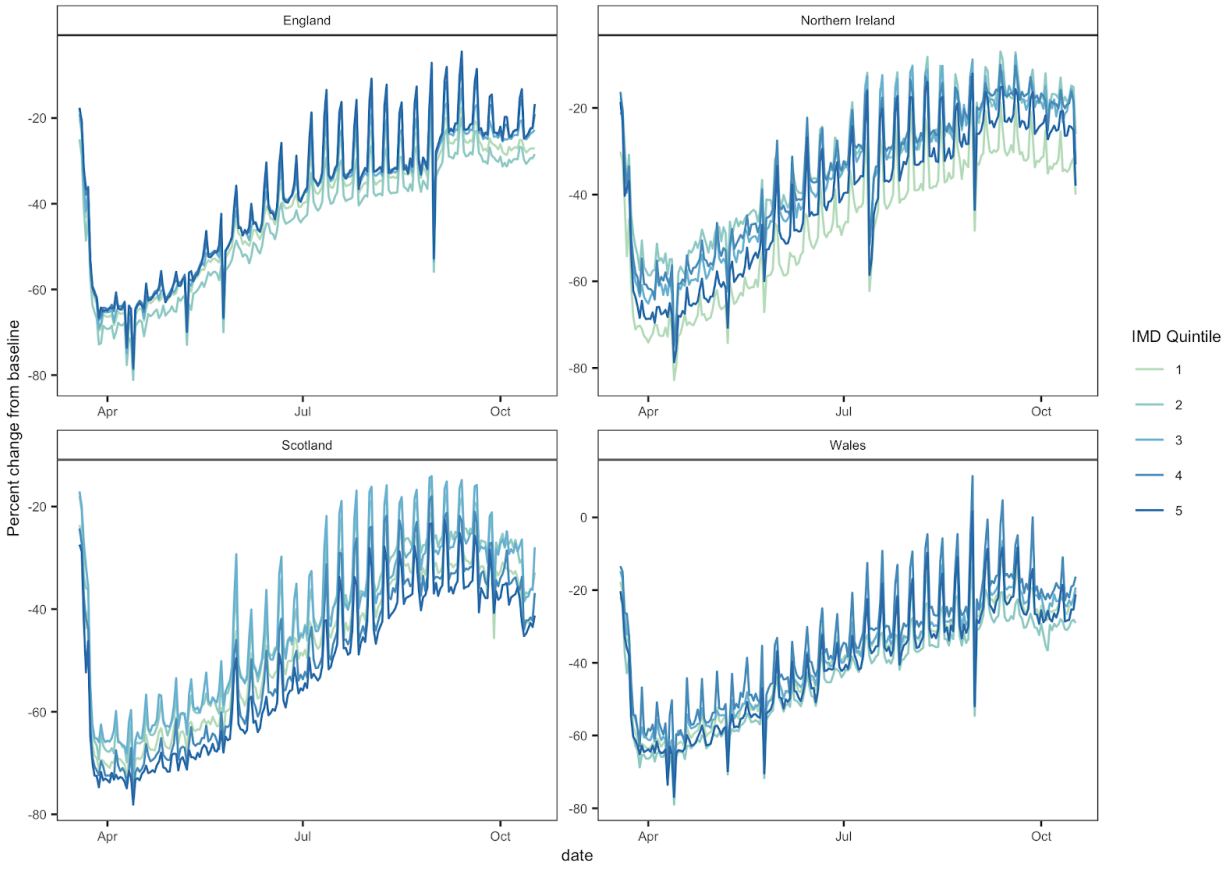


Supplemental Figure 3. The cell-level geographic distribution of the four census variables used in the analysis. In each case, a white cell means the data were missing from the Facebook mobility data and so are not displayed here. In most cases this is due to censoring of low numbers, except for the small discontinuity around Swindon, mentioned in the Main Text. a) Socioeconomic deprivation rank. Each country has a different colour because the measure of socioeconomic deprivation is different in each country. In each case, the darker shade is

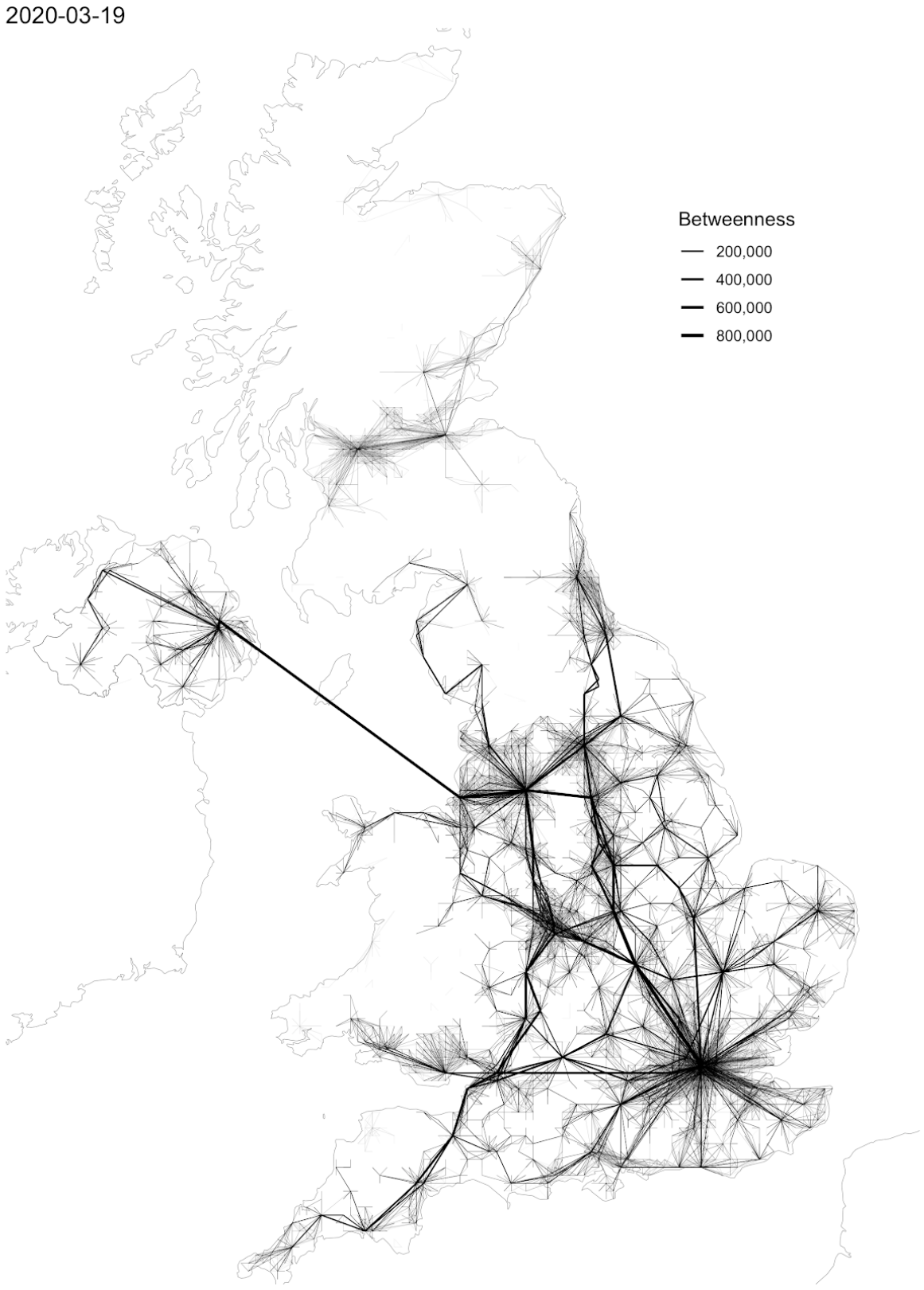
higher deprivation. b) Population density per cell (log scale). c) Percentage of the population self-identifying as any other ethnicity than “Any white background”. d) Mean age of the population resident in each cell.



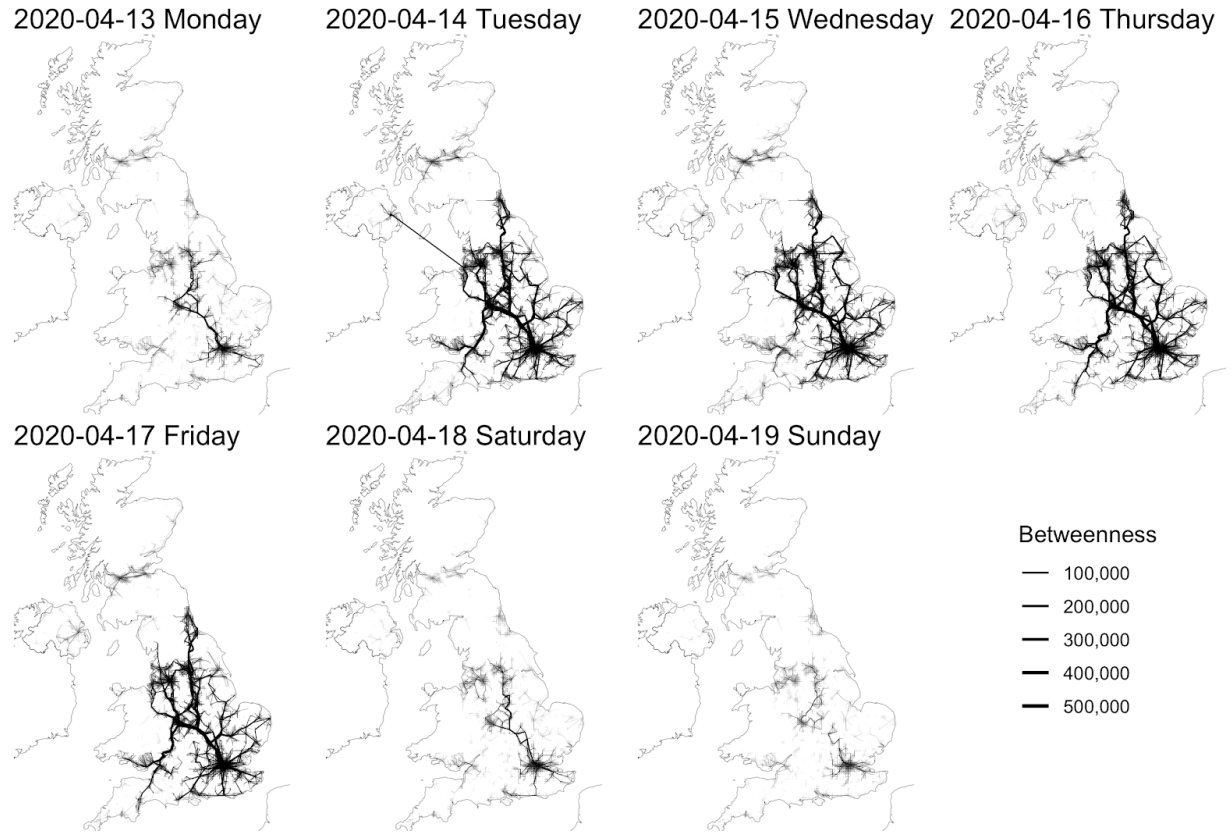
Supplemental Figure 4. A comparison of the percentage of Facebook users and census variables at the cell level. a) socioeconomic deprivation rank, b) mean age, c) percent minority ethnic, and d) population. Variables were aggregated from mid-level census geographies for each country. The mean value of each variable was assigned to intersecting tiles, weighted by small area population estimates. Correlation is shown on the panel as the Pearson correlation coefficient (*R*) and two-sided p values.



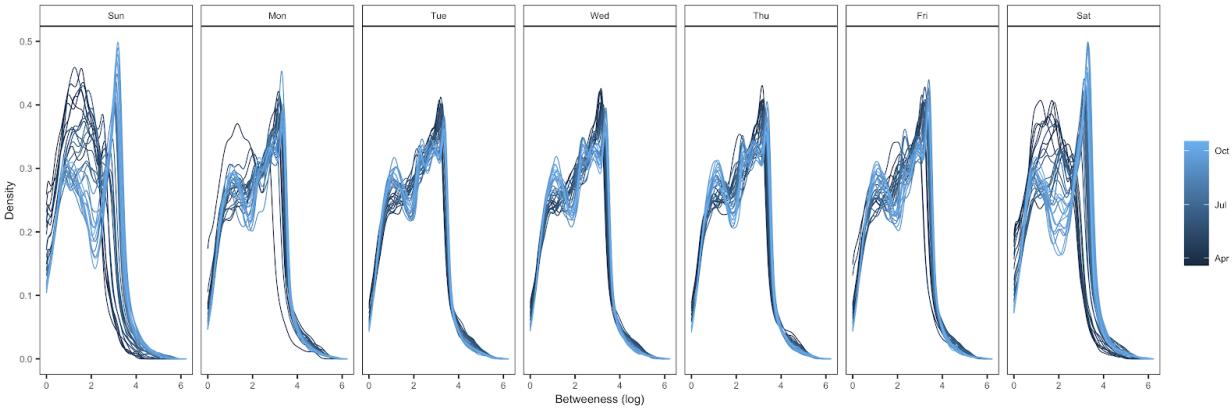
Supplemental Figure 5. A comparison of movement by IMD quintile. Percent change from baseline for movement between cells by IMD quintiles in each country. IMD data was aggregated to cell level and weighted by small area population estimates. IMD quintiles range from 1 (most deprived) to 5 (least deprived).



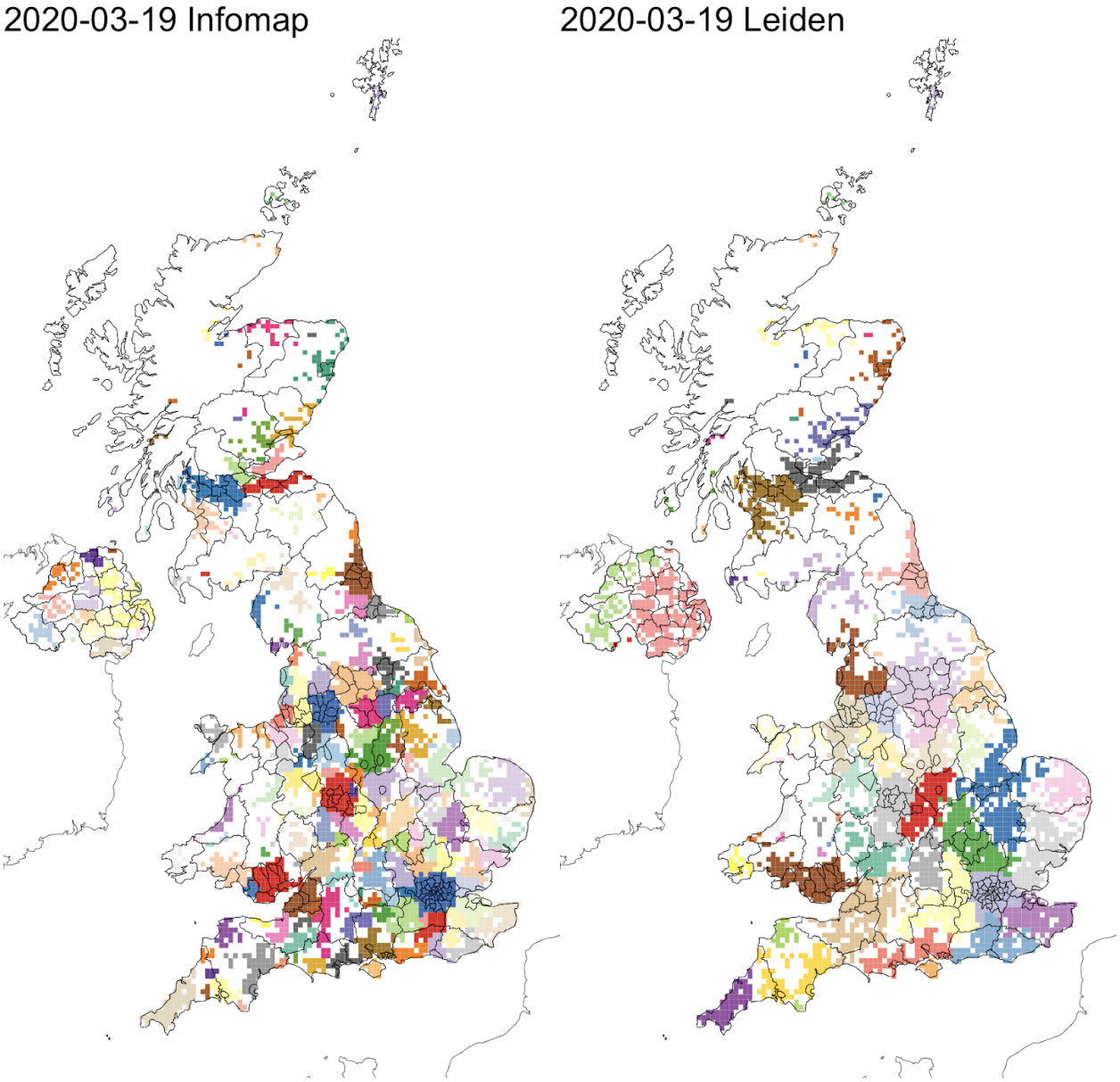
Supplemental Figure 6. Edge betweenness centrality in the network on Thursday March 19 2020. Darkness of the line indicates edge betweenness centrality.



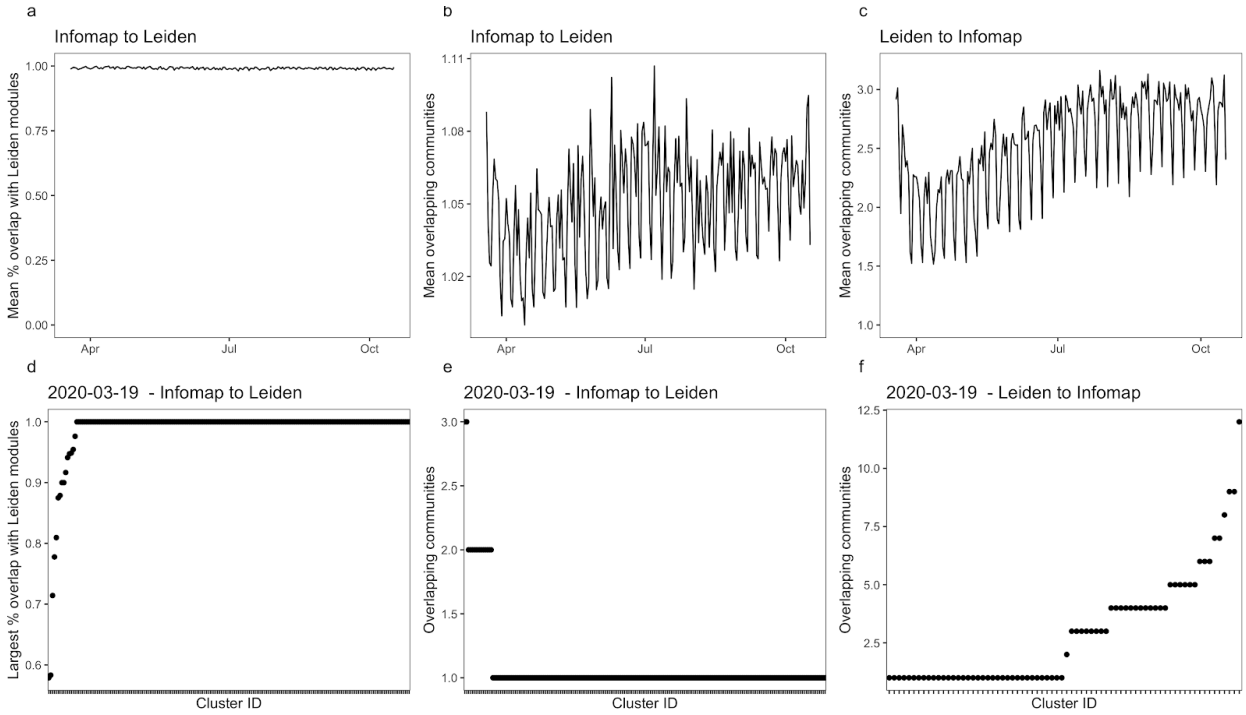
Supplemental Figure 7. Edge betweenness centrality in the network on each day of the week starting Monday April 13th. In the UK in 2020, April 13th was Easter Monday, and is a national holiday. The national lockdown started on March 23rd, and so this time period is during this nationwide intervention. Darkness of the line indicates edge betweenness centrality.



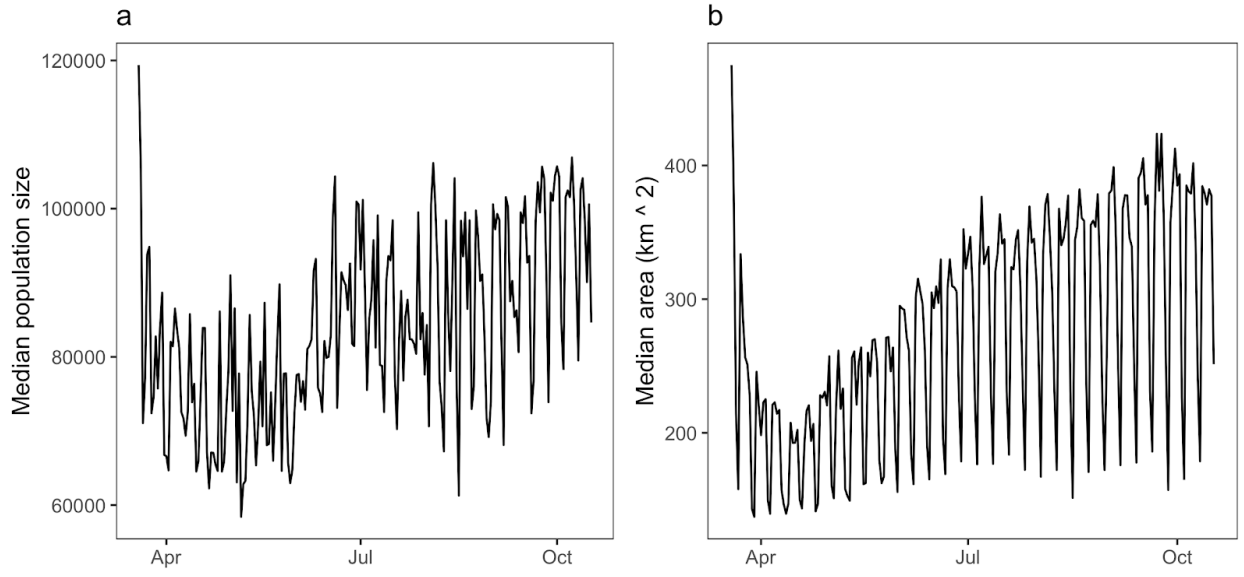
Supplemental Figure 8. The daily density of edge betweenness. Faceted by day of week, showing changes over time on each week day of the study. In the latter part of the study period, increasing numbers of less-central journeys are visible on Tuesdays and Wednesdays compared to those present before national movement restrictions (March 23). This indicates a more fractured network with fewer central journeys.



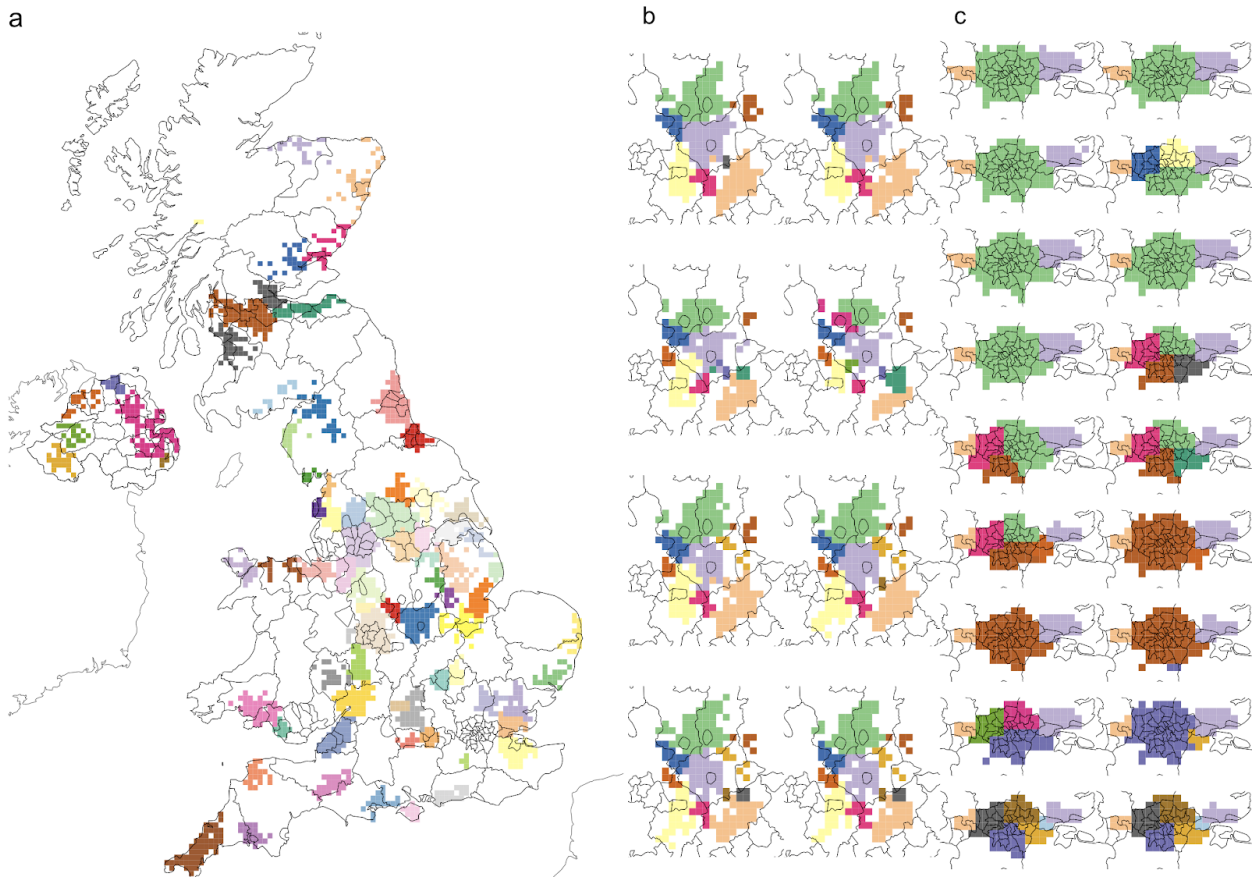
Supplemental Figure 9. Spatial comparison of community detection algorithms. The extent of communities detected by InfoMap (a) and Leiden (b) on March 19th. Leiden communities are largely a superset of communities detected by Infomap, indicating the detection of a different hierarchical structure, but an agreement of community boundaries between the two algorithms.



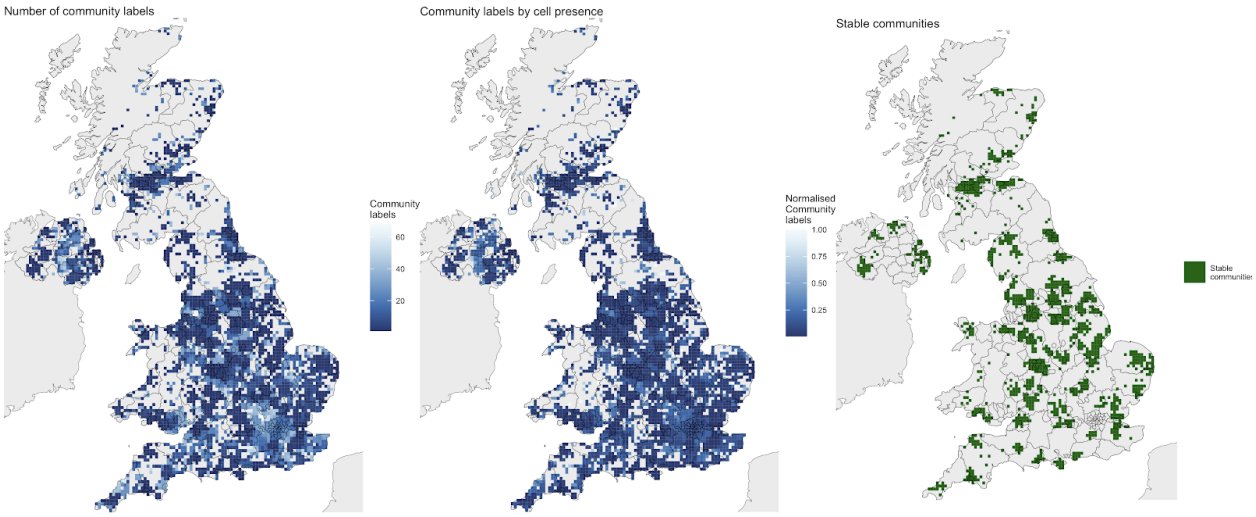
Supplemental Figure 10. Comparing community detection algorithms. A comparison of the spatial intersection between communities detected by the Infomap and Leiden algorithms over time (a) and on March 19th (b), the first day of the time series. Each Infomap community was compared to all Leiden communities and each Leiden community was compared to all InfoMap communities. The percent overlap between communities and the number of intersecting communities were compared. The mean values of each metric were taken to compare changes over time.



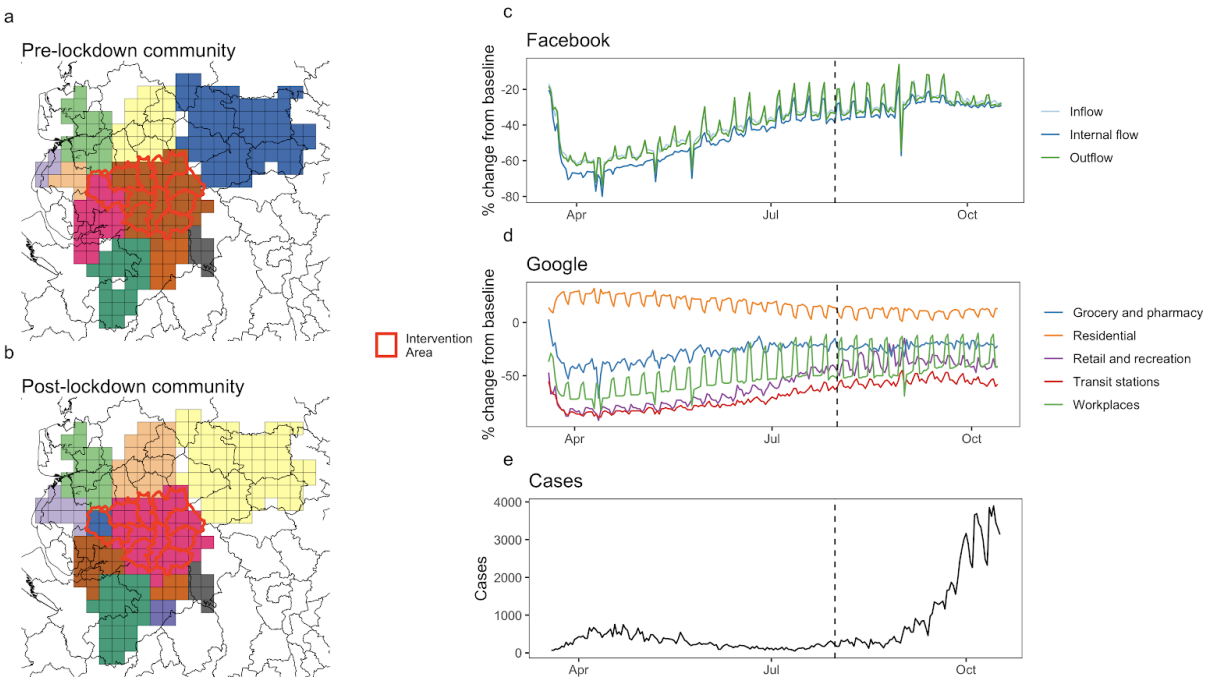
Supplemental Figure 11. Characteristics of InfoMap communities. The median population size (a) and area (b) for InfoMap communities through time. A decrease in the median population size and area of communities during national movement restrictions reflects the higher number of communities and more local patterns of travel. In panel b, decreases on weekends are both the result of changes in the number of communities, and smaller number of cells reported on the weekends due to censoring of cells with low numbers.



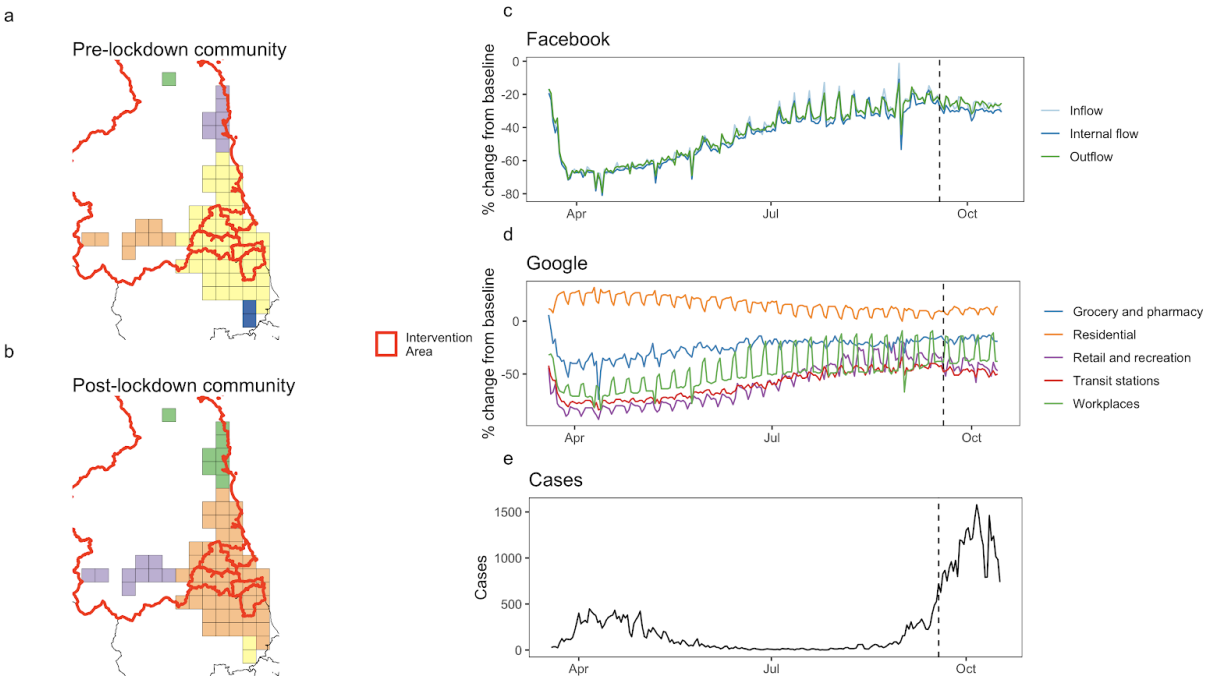
Supplemental Figure 12. Community persistence in the dataset. a) The most persistent communities, those that existed throughout the timeseries, as on March 19th, 2020. b) Community membership from March 19th to March 26th, 2020 in Leicestershire, and c) community membership from March 19th to April 5th, 2020 in London.



Supplemental Figure 13. Persistence of communities. a) the total number of community labels that each cell has had (i.e. number of communities that the cell has ever been in) during the study period. The darkest shade indicates that a cell was always in the same community. b) the number of community labels for a given cell as a proportion of the number of days that cell was present in the dataset. This was calculated as the (number of unique community labels / number of days a cell was present). c) stable communities, marked as those which had the same community label for the entire study period.

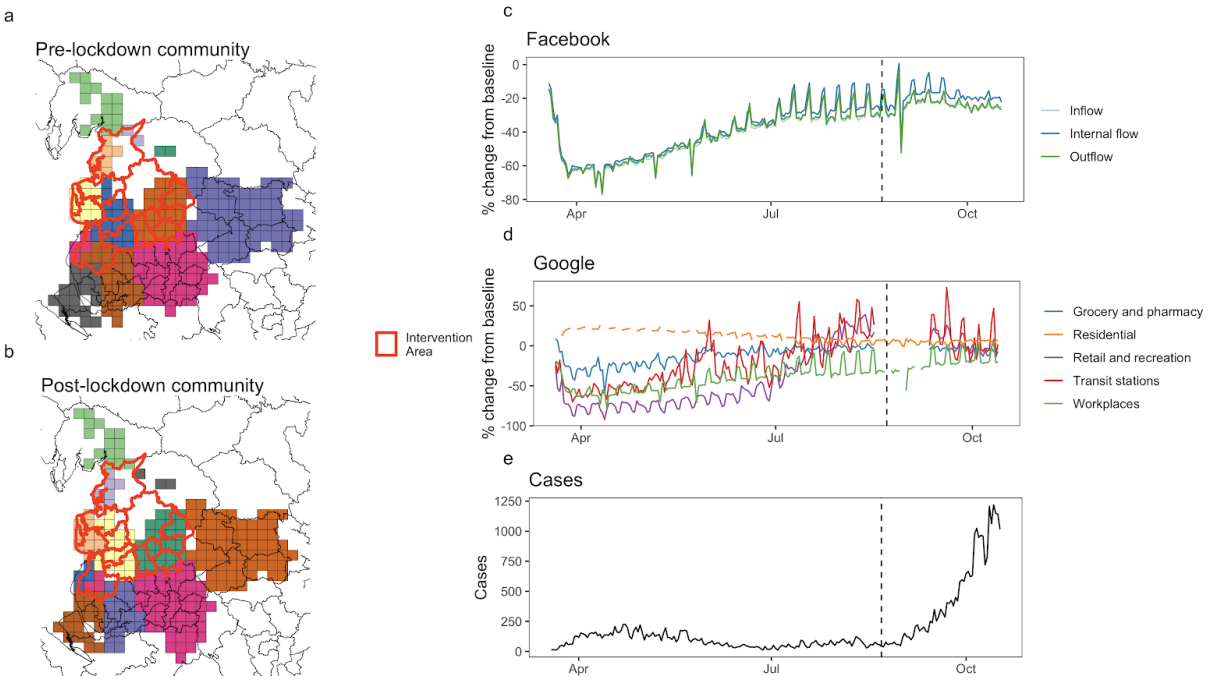


Supplemental Figure 14. Communities connected to Manchester local area restrictions. a) Geographic extent of the Manchester community (green) in the 2 weeks before local interventions, and the area of the interventions (red line). b) Same as a showing 2 weeks after local interventions. c) Movement recorded entering, leaving, or within Manchester in the Facebook mobility data. d) Movement in Manchester recorded in different settings by Google mobility reports, and e) Confirmed COVID-19 cases in all local authorities in the intervention area. The date of local interventions is shown with a dashed line.

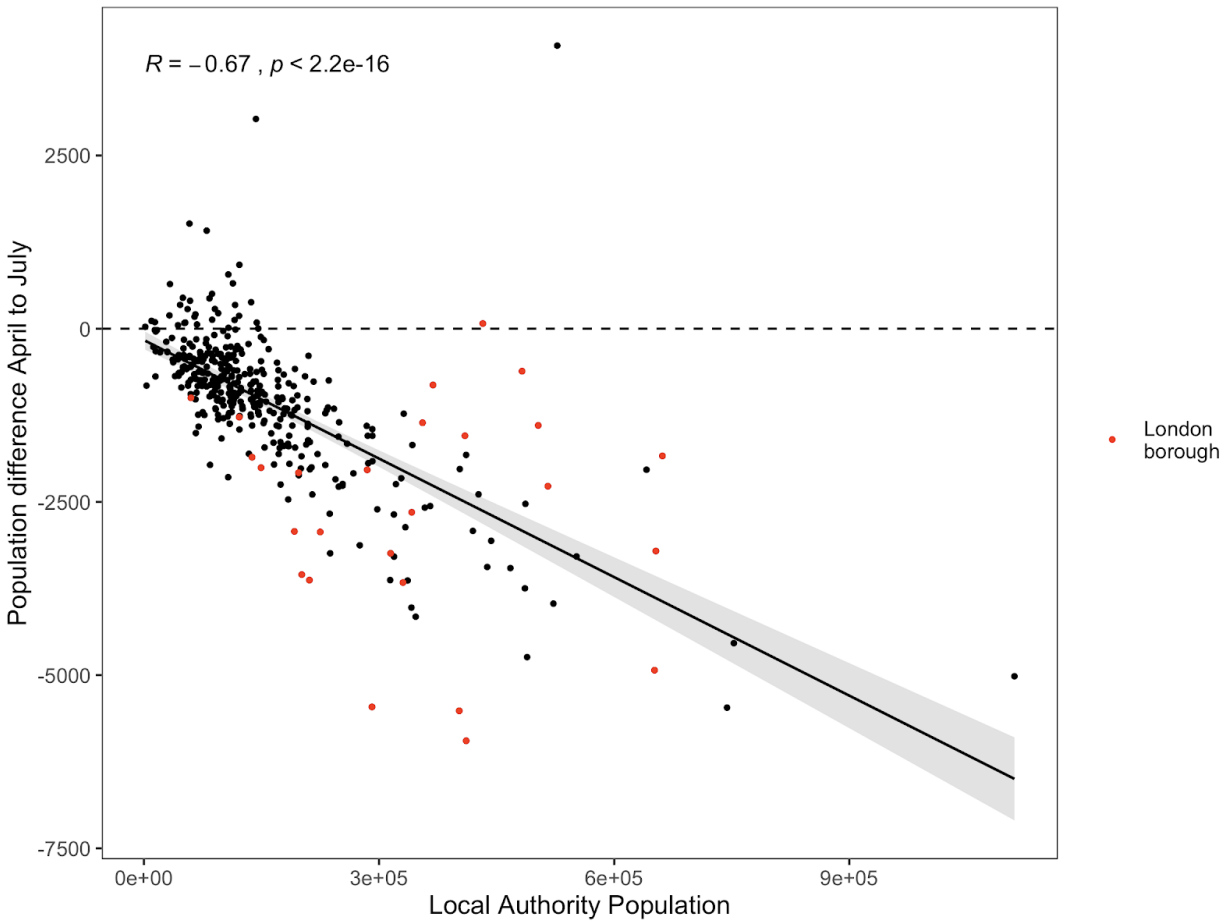


Supplemental Figure 15. Communities connected to North East England local area restrictions. a) Geographic extent of the North East community (green) in the 2 weeks before local interventions, and the area of the interventions (red line). b) Same as a showing 2 weeks after local interventions. c) Movement recorded entering, leaving, or within North East in the Facebook mobility data. d) Movement in Newcastle recorded in different settings

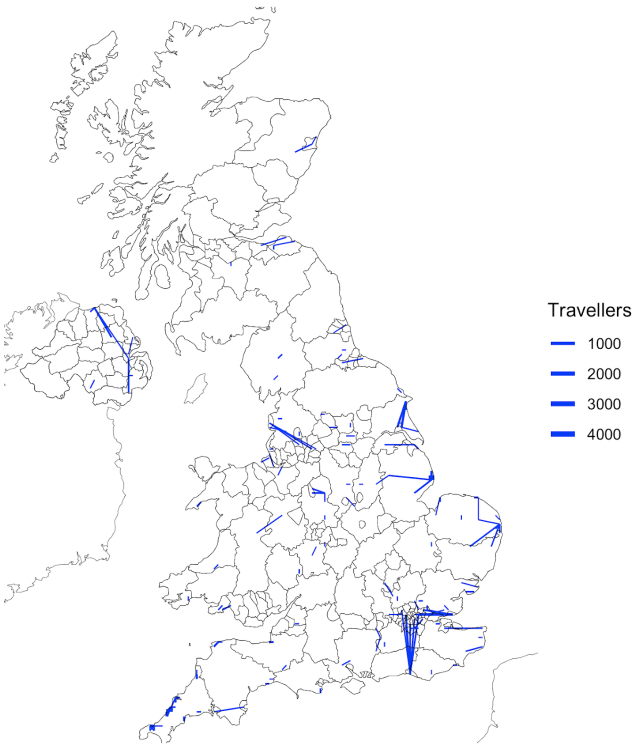
by Google mobility reports, and e) Confirmed COVID-19 cases in all local authorities in the intervention area. The date of local interventions is shown with a dashed line.



Supplemental Figure 16. Communities connected to North West England local area restrictions. a) Geographic extent of the North West community (green) in the 2 weeks before local interventions, and the area of the interventions (red line). b) Same as a showing 2 weeks after local interventions. c) Movement recorded entering, leaving, or within the North West in the Facebook mobility data. d) Movement in Lancaster recorded in different settings by Google mobility reports, and e) Confirmed COVID-19 cases in all local authorities in the intervention area. The date of local interventions is shown with a dashed line.



Supplemental Figure 17. A comparison of population change and local authority population. The Local Authority population from 2020 population estimates from the Office of National Statistics vs the population difference between the April and July Facebook population estimates. Pearson correlation and p-value for association are included. More populous local authorities saw a greater decrease in Facebook population between April and July.



Supplemental Figure 18. Journeys with greater than 100% deviation from baseline in June or July. Size indicates the number of travellers along a given journey.