Explaining the Three Waves of the COVID-19 Transmission in Kenya using a Mathematical Model

Policy Brief

Key Messages

- The first two waves of COVID-19 cases in Kenya can be explained by the presence of different socio-economic groups differing in contact rates and by delayed transmission in rural counties.
- The third wave is likely explained by the introduction of more transmissible COVID-19 variants.
- Schools opening was not responsible for the third wave, but may have been responsible for a slight increase in cases between the second and third waves.
- We project 6,752 (uncertainty range: 6,133, 7,435) new COVID-19 cases, 1,477 (1,402, 1,552) new COVID-19 hospitalisations and 226 (197, 256) new COVID-19 attributed deaths by June 1st 2021.
- A fourth wave would be possible with the introduction or emergence of additional new variants. In the absence of a new factor, we would expect a slow decline with persistent case numbers at a lower level due to the high number of susceptible Kenyans in rural Counties.

A simple mathematical model using the population structure and movement data in Kenya would only predict a single wave. In Kenya we have experienced three waves, hence a more complex model is needed. We find that the first two waves can be explained by allowing the model to include two different socio-economic status (SES) groups, taken together with a delay in transmission in rural counties.

The first wave is explained by the inability of individuals in the lower SES groups to significantly reduce their non-household contact rates. In the first wave, individuals in higher SES groups significantly and rapidly reduced their non-household contact rates in March and April 2020 as shown by Google mobility data (Fig. 1). The higher SES group is well represented by Google mobility data due to smart phone usage. However, individuals in the lower SES group were unable to reduce their contact rate, and therefore contributed most to the first wave. This lower SES group is relatively under-sampled by case detection and fatality detection despite high incidence rates and large population size. The lower SES group is also not well represented by Google mobility data, which depends on smart phone usage.

The second wave is explained by an increase in non-household contact rates among members in the higher socio-economic group (most of whom were susceptible having shielded during the first wave). Further, due to better sampling by case detection and fatality detection, the second wave included a similar case number despite affecting a smaller population (Fig. 2). This modelling approach explains the observed case data in Kenya (Fig. 3) and explains a shift from cases being reported predominantly in public hospitals in the first wave to greater reporting among patients at private hospitals/health facilities in the second wave (Fig. 4). The corresponding predicted rates of hospitalisation are shown in Fig.5 and predicted and observed deaths in Fig.6. While the national figures are dominated by Nairobi, Mombasa and peri-urban Counties, rural Counties were more prominent in the 2nd wave (Fig 7). This means that the second wave could also be partially explained by delayed spread (and/or detection) in rural countries.

The third wave in Kenya is explained by the introduction of more transmissible COVID-19 variants. The differential transmission across two socio-economic groups that explains the first and second wave does not explain a third wave. The third wave in Kenya starts in early March 2021. The third wave affects both social groups, both rural and urban Counties, and is not explained by increased mobility (Fig.1). The third wave in Kenya is best explained by the introduction of more transmissible COVID-19 variants. We explain the third wave by an 80.0% [range 38.6% - 99.7% across counties] increase in transmission per contact starting at the end of January, and a small increase in chance of sampling PCR-positive individuals (OR 1.12 [1.0,1.22]), which could be explained by a more transmissible variant of COVID-19 introduced at some time prior to February 2021. Our prediction based on the modelling should be considered in the light of the results of genomic surveillance which show VOCs are predominant in the third wave (see recent Policy Briefs).

The increased contact rates resulting from schools re-opening in January 2021 do not explain the third wave. Schools re-opening can however explain a very slight increase in case numbers in late January/ early February 2021 which was resolving by March 2021 (i.e. timed between the second and third waves).

We predict that the rate of detected cases, hospitalisations and fatalities will decrease sharply in April (Table 1, Fig. 3, Fig. 5, Fig. 6). However, this will partly be the result of under-sampling lower SES groups and infection rates will remain high (Fig. 2). Significant numbers of Kenyans living in rural counties remain unexposed which will likely cause a consistent but low level of cases for many months. Furthermore, the introduction or spread of additional new variants might theoretically lead to a distinct fourth wave.

Table 1: COVID-19 cases by county group and dates.

County group setting	Number of cases
Mombasa and Nairobi Cases in first wave (up to 1st October 2020)	21,926
Semi-Urban Cases in first wave (up to 1st October 2020)	9,033
Rural Cases in first wave (up to 1st October 2020)	11,540
Mombasa and Nairobi Cases in second wave (1st Oct 2020 – 4th Jan 2021)	41,975
Semi-Urban Cases in second wave (1st Oct 2020 – 4th Jan 2021)	26,158
Rural Cases in second wave (1st Oct 2020 – 4th Jan 2021)	36,858
Mombasa and Nairobi Cases after schools reopening (4th Jan 2021 – 1st March)	11,817
Semi-Urban Cases after schools reopening (4th Jan 2021 – 1st March)	4,014
Rural Cases after schools reopening (4th Jan 2021 – 1st March)	5,237
Mombasa and Nairobi Third wave (1st March – 1st June)	31,507
Semi-Urban Third wave (1st March – 1st June)	13,974
Rural Third wave (1st March – 1st June)	11,316

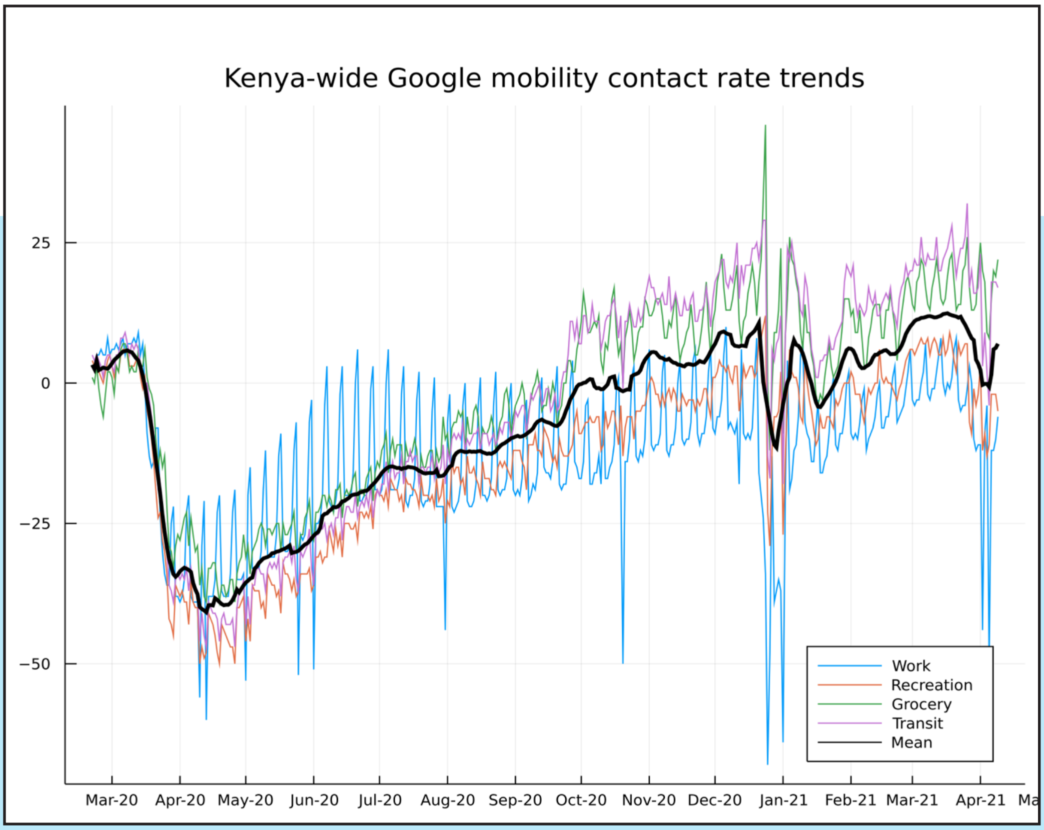

Fig 1: Google mobility trends for smart phone users. There was a significant drop in social activity outside the home for smartphone users across Kenya starting in mid-March. By early November the social activity of smart phone users had returned to pre-pandemic baseline. Y axis records percentage change in contact rates relative to the baseline of prior to the March 2020.

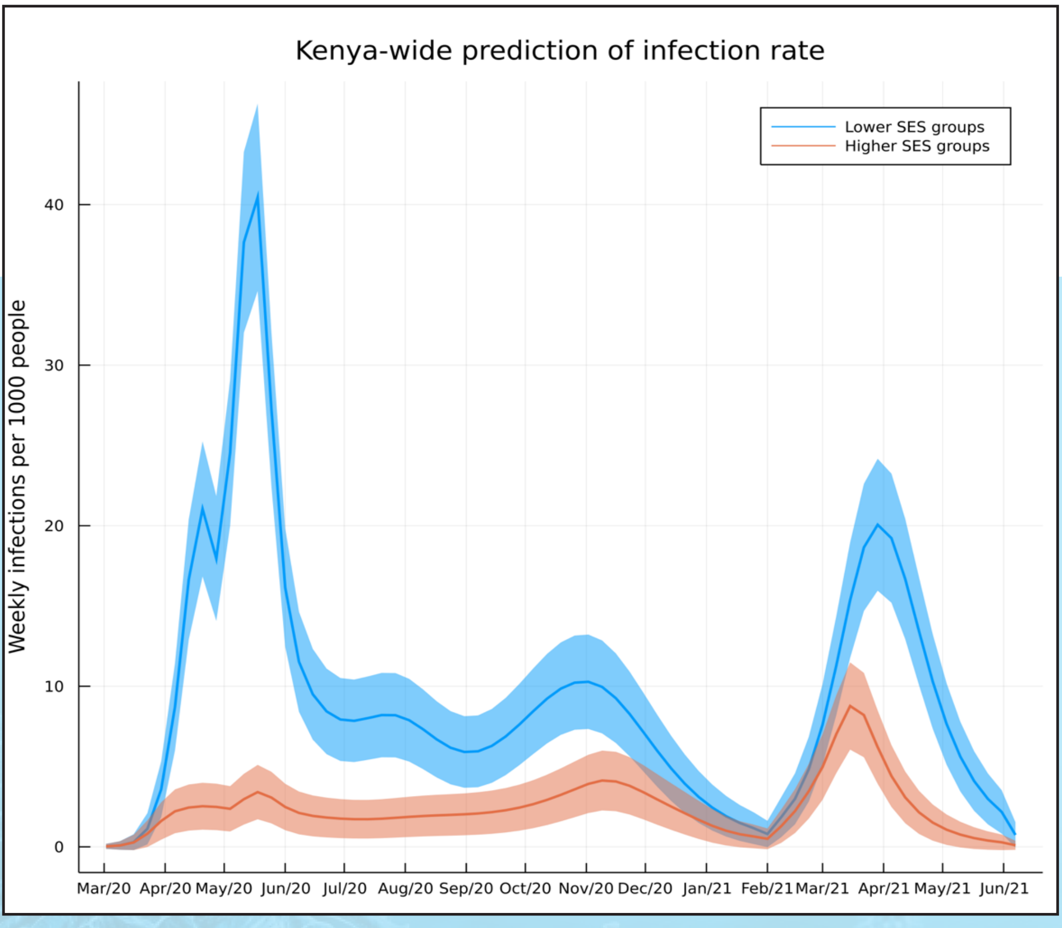

Fig 2: Model prediction for historic and near-future trends in underlying infection rate by SES group. We hindcast that there was a substantial epidemic wave in May 2020 among lower SES groups which was under-sampled. The return of the higher SES groups to near pre-pandemic social activity triggered the second wave (see Fig.1). The third wave affects both groups and is driven by higher transmission rates due to novel variants.

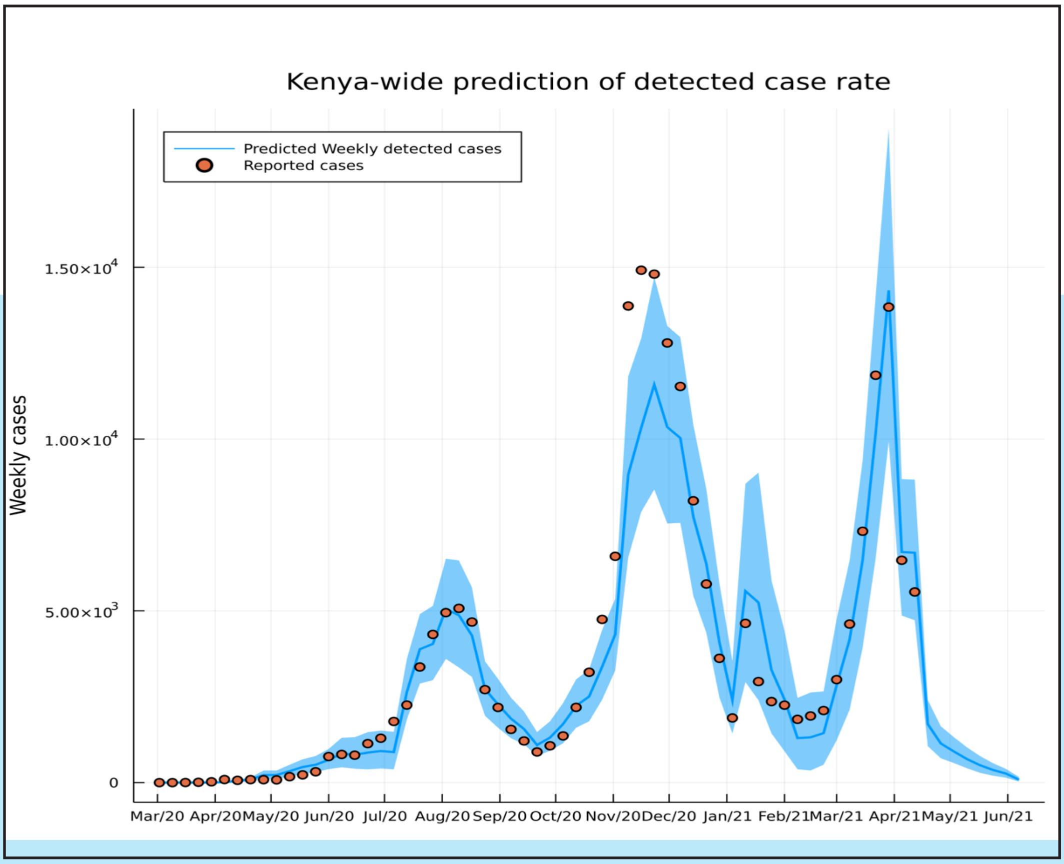

Fig 3: Model prediction and reported case data. The transmission model was fitted to the case and serology data for each of 47 counties to account for local factors in transmission and reporting. The plot shows the combined hindcasting/forecasting for weekly reported case numbers over the 47 Kenyan counties against the observed cases.

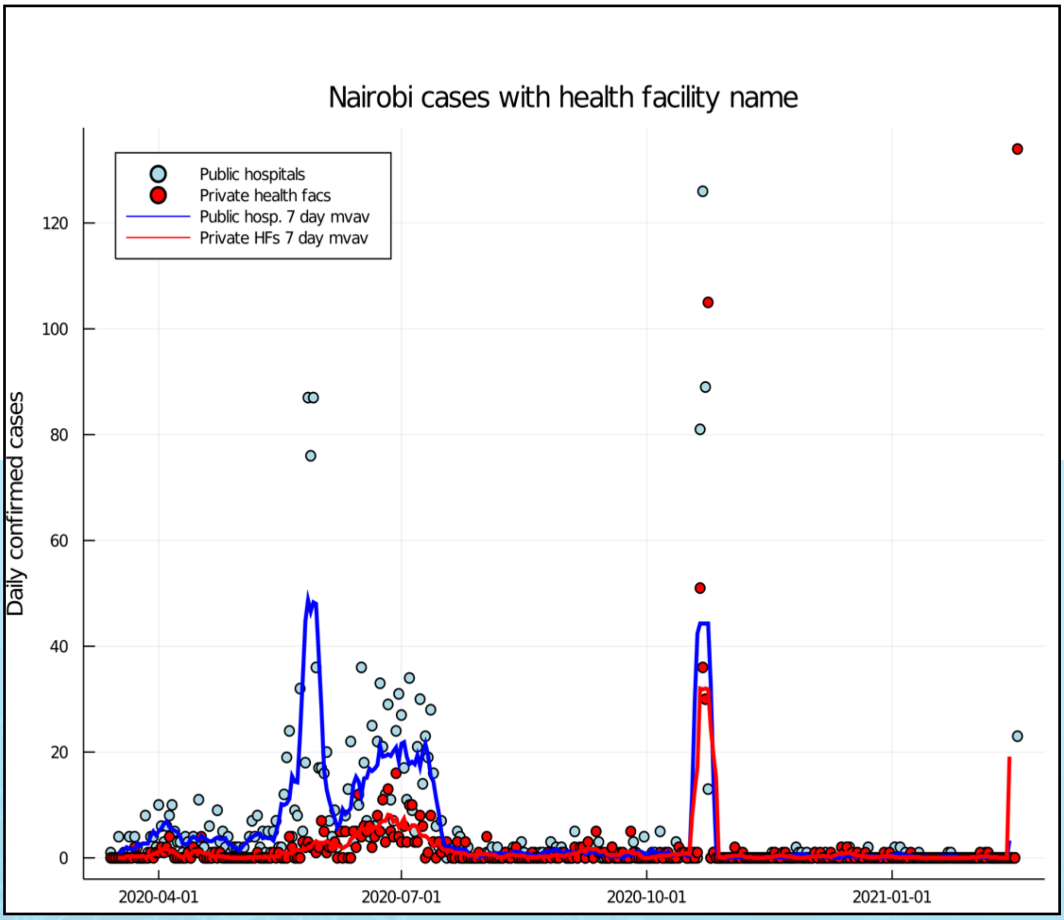

Fig 4: Evidence for shift from public to private hospitals in the Kenyan data. For those cases where a health facility (HF)/hospital is mentioned, public HF/Hospitals predominate in the first wave in Nairobi whereas in the second wave there is a more even mixture of private/public HFs/ Hospitals.

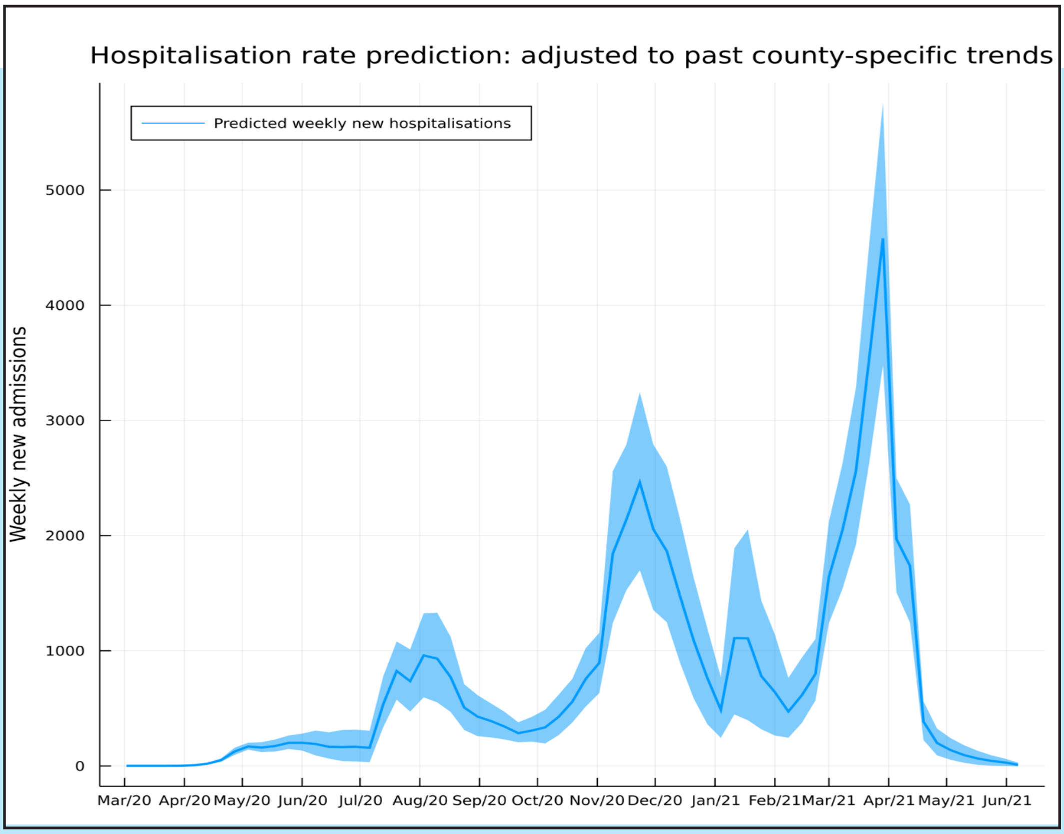

Fig 5: Projected weekly rates of hospital admission. We assume that the underlying biases in favour of detecting cases among higher SES groups compared to lower SES groups are also reflected in hospitalization rates per case, and calibrate the bias to match observed cumulative hospitalizations in each county up until 1st December 2020. After December 1st we project hospitalization rates by assuming similar risk per infection per SES group. Lack of detailed data on hospitalizations are a limitation.

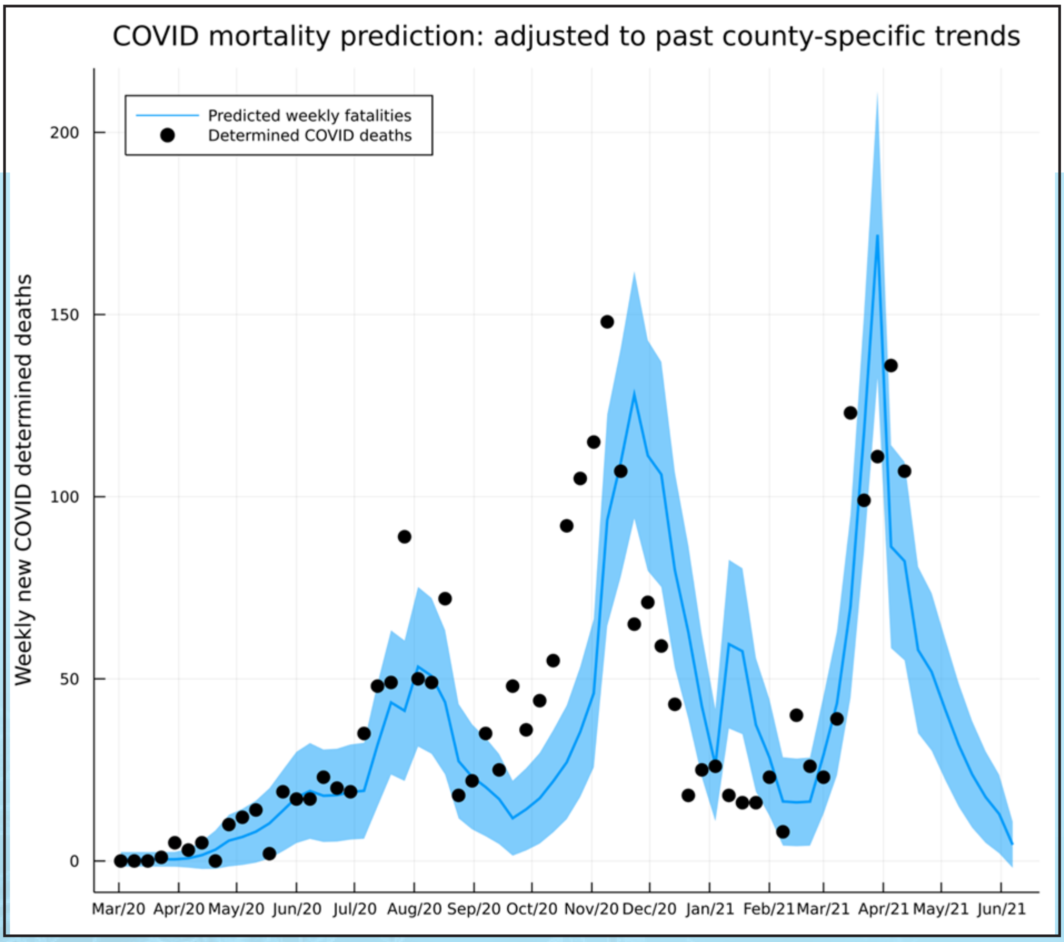

Fig 6: Projected weekly rates of deaths attributed to COVID-19 disease with a confirmatory test. We assume that the underlying biases in favour of detecting cases among higher SES groups compared to lower SES groups are also reflected in fatality rates per case per SES group, and calibrate to match observed cumulative determined COVID-19 fatalities in each county up until 31st January 2021. After January 31st we project fatality rates by assuming similar risk per infection per SES group.

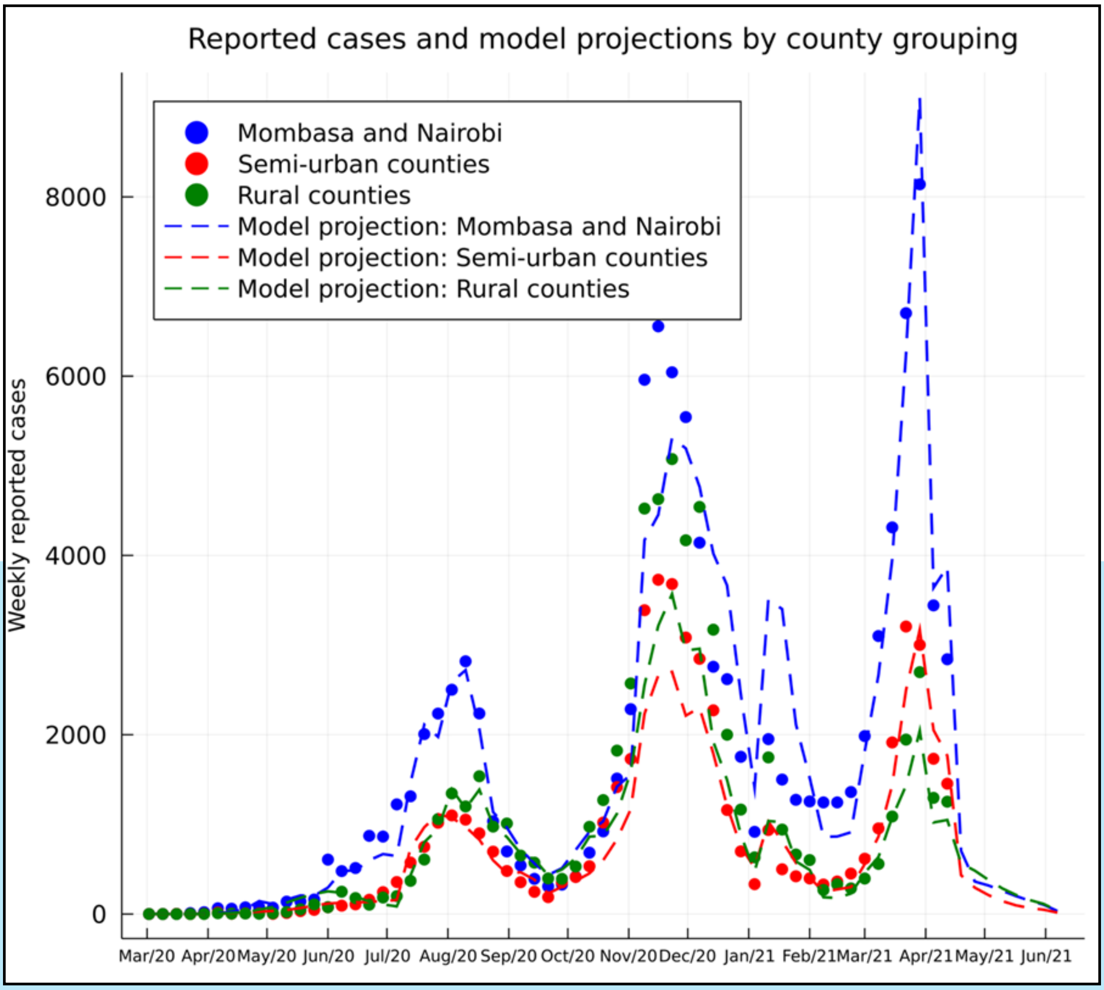

Fig 7. Breakdown of cases and model projections by county group. Dots indicate total weekly reported cases by county group, dashed lines are model predictions.

References

Serina Chang et al., "Mobility Network Models of COVID-19 Explain Inequities and Inform Reopening," Nature Publishing Group 589, no. 7840 (2020): 1–26

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