Assessing the effectiveness of perimeter lockdowns as a response to epidemics at the urban scale: the case of Madrid

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During the COVID-19 pandemic we have become acquainted with a battery of measures to fight the spreading of the infection produced by SARS-CoV-2 at different scales. At first, there was little option other than pursue non-pharmaceutical interventions (NPIs) as travel bans and lockdowns of different extension. At the urban level, one of these tools has been the so-called localized or perimeter lockdowns. When the epidemiological situation of an area worsens, perimeter lockdowns aim for protection to the rest of the system by banning travels in and out, and reinforcing awareness and action on the affected areas. This strategy is argued to result in lower social and economic costs as compared to larger-scale restrictions, but there are also some concerns about their usefulness in effectively controlling an epidemic at a urban scale. This strategy is a rare tool only implemented in Santiago de Chile and Madrid to our best knowledge [1]. The case of Madrid caused certain sociopolitical controversy, and even jumped into scientific literature [2], [3]. Inspired by this, in this work we try to settle the question on the effectiveness of perimeter lockdowns (PLs).

We use a data-driven stochastic metapopulation SIR epidemiological model of a city which responds to the epidemic spreading with PLs. Our model thus consists in a population of N individuals distributed in a networked structure of V patches that represent urban districts. Patches are connected through data-driven mobility flows. Inside every subpopulation the homogeneous mixing assumption is considered. Apart from the disease parameters, related in this settings through $R_0 = \beta T_I$, where R_0 is the basic reproductive number, β is the transmissibility rate and T_I is the infectious period, there is also a general mobility parameter κ, a transmissibiity reduction parameter χ, and a risk incidence threshold Θ. When a subpopulation in the system shows a 14-day cumulative incidence rate above a certain threshold Θ, travel restrictions in and out of the affected area i are activated and a local transmissibility reduction is carried through lowering χ, so that $\beta_i = \chi_i \beta$.

We explore under which circumstances PLs could be a good response of epidemic control and we find that the window of opportunity is very tight, making them rather useless in most realistic situations. Mobility reductions by itself do nothing unless κ is moved to unrealistically low values. Indeed, achieving high enough transmissibility reductions, that is, low χ, is key to locally control the spreading but even more importantly is to act as soon as possible, very low Θ and this could not be that easy to achieve. Given the interconnectedness of the system, synchronization of the epidemic trajectories in every subpopulation takes place and the full system is quickly invaded and at risk. This synchronization is something that can be seen by simple inspection of the real data in Madrid. Our parsimonious model reproduces these qualitative aspects well. This phenomenon, due to highly interconnected mobility flows among districts, is what hinders the effectiveness of PLs at the urban scale.

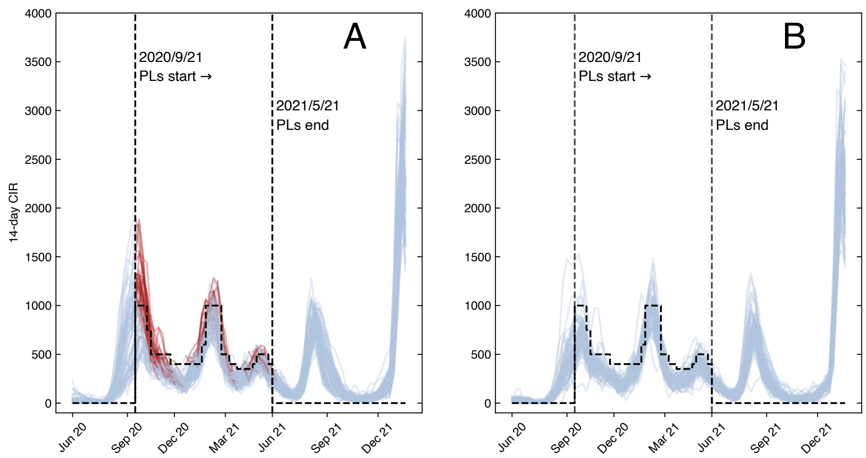

FIG. 1: Real 14 day cumulative incidence rate time series for the basic health zones (BHZs) in Madrid city. Left: Trajectories for BHZs that during some time period experienced a PL. In red, the period in which they were under a PL. Right: Trajectories for BHZs that never were confined. Vertical dashed lines mark the beginning and the end of the perimeter lockdown strategy in Madrid and step-wise horizontal dashed lines signal the risk threshold considered by the authorities to activate the PLs.

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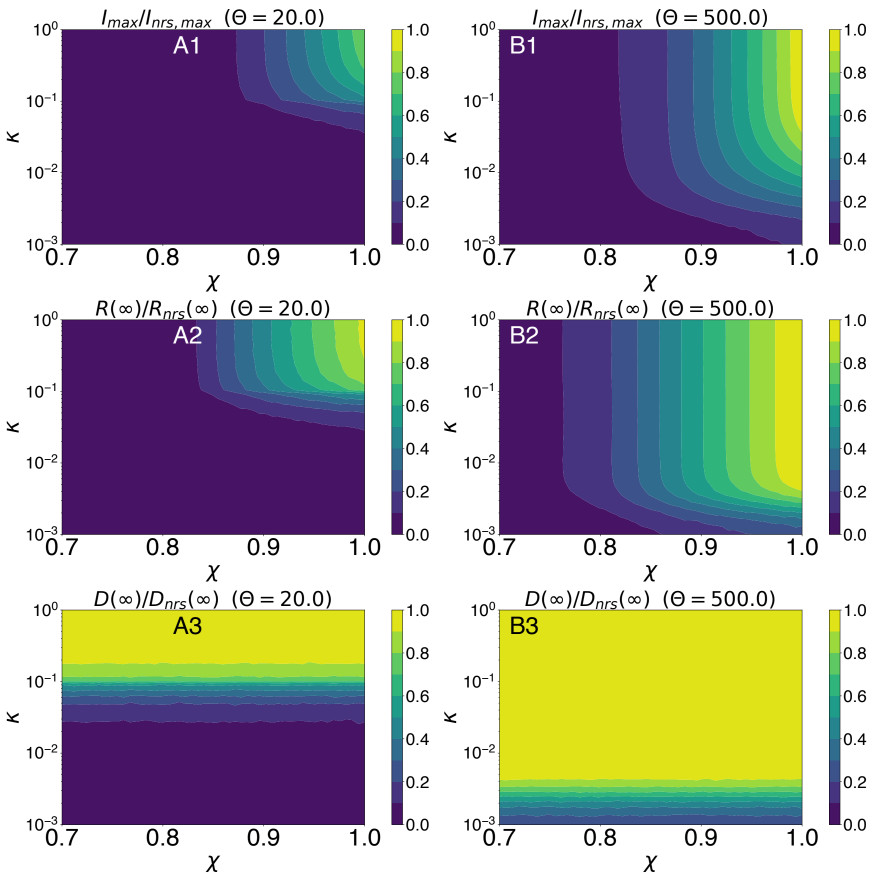

FIG. 2: Color maps show epidemic impact when varying simultaneously κ and χ. Plots A1, A2, and A3 show the peak incidence, prevalence, and locked districts fraction, respectively, in (χ, κ)-space for threshold $\Theta = 20$. Plots B1, B2 and B3 show the same observables now for $\Theta = 500$. Quantity values are normalized with respect to a no-response scenario.