Countries and cities around the world have resorted to unprecedented mobility restrictions to combat Covid-19 transmission. Here we exploit a natural experiment whereby Colombian cities implemented varied lockdown policies based on ID number and gender to analyse the impact of these policies on urban mobility. Using mobile phone data, we find that the severity of local lockdown rules, measured in the number of days citizens are allowed to go out, does not correlate with mobility reduction. Instead, we find that larger, wealthier cities with a more formalized and complex industrial structure experienced greater reductions in mobility. Commuters are more likely to stay home when their work is located in wealthy or
commercially/industrially formalized neighbourhoods. Hence, our results indicate that cities’ employment characteristics and work-from-home capabilities are the primary determinants of mobility reduction.

**Introduction**

Across the world, governments and scientists alike have struggled immensely with the question of which policies will most effectively reduce the spread of COVID-19. In a cross-country analysis of case data, Hsiang *et al.* find that in six countries various policies ranging from full lockdown to paid sick leave prevented or delayed an estimated 495 million cases from January-June 2020, but that the effects of specific policies differed from country to country (1). Evidence from China (2) and across Europe (3) demonstrates clear evidence that full lockdown is by far the most effective measure in curbing spread. However, it is not yet clear how local economic conditions affect policy success.

Epidemic mitigation policies are not implemented in a vacuum. For instance, a tech hub has many jobs that can be performed remotely with relative ease, while a manufacturing center does not. Globally, cities with many teleworkable jobs have been better able to reduce work commutes (4, 5). More generally, wealthier cities and wealthier neighborhoods have been more adept at reducing urban mobility (6–9), and as well experienced lower Covid-19 death rates at least in the UK and USA (10, 11). However, the relationship between lockdown severity, city wealth, and observed mobility reduction remains not well understood. For example, are harsh mobility restrictions as effective in less wealthy cities? Or does the nature of the local economy outweigh policy severity?

Latin American countries generally had more time to prepare for the in-coming pandemic and develop appropriate policy measures (12). In Colombia, Ecuador, and Panamá,
residents were allowed out for essential trips on days of the week corresponding to their national ID number and/or gender. We can quantify the severity of this type of policy via, i.e., the share of residents allowed out daily. We specifically focus on Colombian cities which implemented local variations of these policies. For example, in Bogotá residents were allowed out every other day based on their gender, whereas Florencia allowed just 10% of residents out daily (Figure 1). Additionally, socioeconomic conditions vary significantly between Colombian cities, with the largest cities having much higher composite wealth and industry sophistication \((13, 14)\). These variations in policy and wealth represent a natural experiment in which we examine the relationship between policy severity, city wealth, and observed mobility reduction.

We use mobile phone data (call records) to characterize changes in city residents’ urban mobility in an 11-day period beginning with the introduction of local lockdown measures. Urban mobility metrics from mobile phones have frequently been used to quantify mobility reductions in the wake of COVID-19 as well as other infectious diseases, both to characterize lockdown measures \((2, 15)\), and to predict epidemic spread \((16–18)\).

Our key finding is that more severe mobility restrictions have no significant impact on local mobility reduction levels. An implication of this finding is that fine-tuned restrictions, which calibrate the share of people allowed out daily, do not lead to a proportional decrease in mobility. On the other hand, city size is strongly correlated with mobility reduction, both in terms of trip frequency and daily distance traveled. Hence, cities with higher labor formality, GDP per capita, and industrial complexity experience more reduced mobility - irrespective of the policy imposed. Furthermore, within cities, commuters to wealthy and commercial areas are most disrupted. Hence, both high income and associated service workers are more likely to stay at home. Taken together, these results have important implications for the design of lockdown policies, the success of
which depends critically on local economic conditions.

1 ID and gender-based mobility restrictions

During the early stages of COVID-19 exposure, the Colombian government ordered municipal governments to impose local mobility restrictions. Most municipalities (22 departmental capitals) imposed “pico y cédula” restrictions in which residents were allowed out on certain days corresponding to the terminating digit of their national ID numbers. However, the ID numbers allowed out daily varied between municipalities (Fig. 1A). For example, two of the smallest municipalities only allowed residents out roughly one weekday per every two weeks (10% of residents allowed out daily). The largest city and capital, Bogotá, allowed males/females out on alternating days (50% allowed out daily).

In order to quantify the severity of municipal policies, we collected local policy advice for the principle departmental capitals from government websites and/or social media. Whereas these ID/gender-based measures were advertised widely, and enforced in certain venues (e.g. public transit, access to banks/supermarkets), the extent of policy enforcement/adherence is generally unclear across municipalities, especially in the informal labor sector.

For each departmental capital, we computed the average % of residents allowed out daily for 11 weekdays (April 13-27) in the pandemic’s early stages (Fig. 1B). This corresponds to an initial ‘lockdown’ period in which all municipalities had recently enacted ID/gender-based restrictions. Interestingly, on average smaller municipalities permitted fewer people out daily (Pearson’s $\rho = .39$). Hence, with strong adherence, we would expect that residents of smaller municipalities traveled less frequently during lockdown. In the following section we will investigate whether this is observed in practice.
Figure 1: Colombian municipalities administered locally varying policies in which residents were allowed to go out for essential purposes on days corresponding to their national ID/gender. A: During the study period, Medellín allowed out an average of 3 ID numbers daily (30% of residents). B: The capital municipalities (points, size proportional to population) of the most populous departments in Colombia, colored by the average share of residents allowed out per weekday from April 13-27. Departments are shaded by GDP per capita. C: Users nationwide reduced their mobility greatly from March 19 (end of week -1), when the government first announced national lockdown-related policies. From March 19-April 9 (weeks 0-2), residents nationwide were instructed to stay home unless absolutely necessary, but localized policies took effect from April 6 (week 2) in all municipalities except Bogotá, which implemented the pico y género policy on April 13 (week 3).
Figure 2: City size, rather than policy severity, is associated with more pronounced reduction in residents’ trip frequency. A: Empirical distributions of trip frequencies for detected residents in municipalities of interest. D-E: Municipality-level mean trip frequency (points, size proportional to population, color to policy severity) during lockdown is not related significantly to policy severity or population. B-C: Increasing population (but not severity) has a strong reducing effect on municipality-level median reduction in trip frequency (standard error bars and 95% confidence intervals calculated via bootstrapping).


2 Effects of policy severity and city size on lockdown mobility

In order to evaluate the effects of localized mobility restrictions, we computed mobility indicators derived from call detail records (CDRs) for 22 out of 23 of Colombia’s departmental capital municipalities (omitting one on account of low sample size). For each resident we compute trip frequency which is the % of active days (days in which the user makes or receives a call) in which they travel 1 km from their home cell, and daily distance traveled which is the average distance traveled from their home cell on active days.

In order to assess changes in mobility relative to pre-lockdown, we also compute these metrics for a baseline period prior to COVID-19.

We find that most users across all municipalities reduced their daily distance traveled during lockdown (Fig. 1C). However, the extent of the reduction varied greatly across municipalities. We display municipality-level distributions of trip frequencies before and after lockdown in Figure 2A, and relative change (from baseline) in daily distance traveled in Figure 3A. Most municipalities had a mean lockdown trip frequency of 25 – 30% (Fig. 2B-C). This represents a reduction in mobility from baseline levels that were 20 – 45% higher, with the largest reduction in Bogotá (Fig 2D-E).

To what extent does policy severity impact changes in trip frequency and daily distance traveled relative to baseline levels? We find no evidence for an effect on daily distance traveled and very limited evidence (p = .11) for an effect on reduction in trip frequency. If a municipality reduced the amount of residents allowed out daily by 10%, residents on average decreased their trip frequency by only a meager additional 0.4% (controlling for population, see SI 1B).

This finding - that more severe local restrictions do not result in proportional re-
Figure 3: Residents of larger, wealthier municipalities with more formalized labor experienced more pronounced reductions in daily travel distance traveled during the lockdown period. A. Empirical (kernel density) municipality-level distributions of relative change in daily distance traveled from the basal period to lockdown. Vertical dashed black (grey) lines represent municipality level median (quartile) estimates. Municipalities are colored by policy severity (as in Fig. 2). B-E: Municipality population, as well as economic complexity, GDP per capita, and labor formality are associated with more pronounced relative change in daily distance traveled.
ductions in mobility - is unexpected and important, especially considering the breadth of findings on the role of mobility restrictions in controlling infection spread (2, 3, 19). We hypothesise that urban residents are more influenced by their economic capacity to comply with rules than by the precise measures implemented locally. As a first step, we investigate the role of urbanization (city size) in mobility reduction. An abundance of previous work has shown that city size is associated with economic prosperity - larger cities boast higher wages and GDP per capita, and a higher skilled as well as more formalized labor force working in more sophisticated sectors (13, 14, 20–23). These factors generally improve residents’ capacity to work remotely and reduce their mobility (6, 8, 9, 17, 24).

We find that city size has a strong bearing on mobility reduction. Residents of larger municipalities had more pronounced reductions in trip frequency - for every tenfold increase in municipal population, the average resident reduced their trip frequency by an additional 9.1%. Additionally, a tenfold increase in population was associated with a 17.1% additional reduction in daily distance traveled relative to the basal period. Moreover, when we aggregate to the municipality level, we find that city size explains substantial variance in both cases with $R^2 = .43$ for change in trip frequency (Fig. 2E) and $R^2 = .49$ for relative change in daily distance traveled (Fig. 3B).

Hence, there is something about larger cities that enables residents to substantially reduce mobility despite less severe mobility restrictions. We find that the median relative change in daily distance traveled is significantly associated ($p < .01$) with municipality-level economic variables including GDP per capita and labor formality rate (Fig 3D-E), defined as the ratio of formal workers to the working age population (14). We construct a metric of industrial complexity (14, 25, 26), which is also, as expected, associated with reduction in daily distance traveled. None, though, are better predictors than city size.
3 Intra-city variation by socioeconomic status

City size has a clear effect on mobility reduction, but - especially in Latin America - cities themselves are characterized by high internal income inequality (27). Here we investigate how this drives mobility reduction at an intra-city level. Specifically, we ask if wealthier residents experienced higher levels of mobility reduction.

We use the stratum number assigned to each residential block, as a proxy for residents’ socioeconomic status (28). Stratum is a government-assigned designation corresponding to local housing conditions and quality, and has been frequently used to characterize socio-economic status (29,30). The stratum system encompasses 6 strata of progressively increasing socioeconomic status, with 1 signifying poor quality, often informal housing and 6 signifying the richest neighborhoods (stratum 6 is only present in select cities). Most residents countrywide live in medium stratum (2-3) housing.

In order to examine the effects of stratum on mobility reduction, we calculate changes in trip frequency and relative change in daily distance traveled as a function of stratum for each municipality (Fig. 4A-D). In general, wealthier residents experienced more pronounced reductions in both daily distance traveled and in trip frequency - in line with similar trends observed in cities across Latin America, Europe, the USA, and Asia (6–9,17,24). Pooling across municipalities, we find that a one standard deviation increase in stratum was associated with a $-1.82\%$ decrease in $\Delta$ trip frequency (1 km) and a $-3.82\%$ decrease in Rel. $\Delta$ daily distance traveled ($p < .01$ in both cases, estimates represented by dashed lines in Fig. 4E). The importance of stratum varies across municipalities - the effect of stratum on $\Delta$ trip frequency is significant ($p < .05$) in 15 out of 22 municipalities, and on Rel. $\Delta$ daily distance traveled is significant in 10 out of 22 municipalities (coefficient estimates displayed in Fig. 4E).
Figure 4: Within municipalities, higher socioeconomic status was generally associated with more pronounced mobility reduction. A-B: Boxplot distributions of residential change in trip frequency and daily distance traveled for varying stratum. C-D: Municipality-level median estimates of change in trip frequency/daily distance traveled for varying stratum (municipalities ordered by population). E: Municipality-level coefficient estimates for the effect of stratum on changes in trip frequency and daily distance traveled (errorbars represent 95% confidence intervals). Dashed lines represent average effects over all municipalities.
We have observed effects of socioeconomic inequality on mobility reduction at both an inter-city (previous section) and intra-city level. However, we now ask - are inter-city effects explained by differences in socioeconomic composition across cities? In other words, is there some effect of city size that is not simply captured by stratum variation? In order to disentangle these effects, we split each municipality into low (1−2) and high (4−6) stratum subsets and examine the effect of city size on mobility reduction across these subsets. For both groups, we find that increasing city size is associated with a greater reduction in trip frequency and daily distance traveled. The effect is comparably pronounced across low/high stratum groups - a tenfold increase in population is associated (p < 0.01) with an additional 7.1%(low)/6.7% (high) reduction in Δ trip frequency (1 km) and an additional 14.3/22.5% reduction in Rel. Δ daily distance traveled.

Overall, these findings underscore role of city size in mobility reduction. We find that this effect is not limited to any socio-economic class in particular, but is instead consistent across strata. In other words, both the city in which a person resides and the socio-economic status of their own neighborhood influence their level of mobility reduction.

4 Disruptions to work commutes

Building on previous findings that show wealthier cities have more jobs that can be performed remotely (5,31,32), we investigate how city size and socioeconomic stratum are linked to work commute disruptions. We examine whether (i) city size is linked to more commute disruptions; and (ii) whether residents’ home/work stratum is linked to their tendency to forego their commutes.

As is standard practice, we identify home-work commutes via persistent origin-destination flows (33). We define the commute disruption rate as the % of flows that cease during lockdown (see SI Section 1A/2 for details). As with trip frequency and distance traveled,
we find, as expected, that more commute flows are disrupted in larger cities (Fig. 5B). For every tenfold increase in population, the municipality-level commute disruption rate rises 18.1% ($R^2 = .47$, $p < .01$), while policy severity has no significant effect.

Figure 5: Increasing effects of city size and socioeconomic stratum on commute disruption rate. A: Effect of $log(population)$ on estimated commute disruption rate (errorbars represent standard errors, 95% confidence intervals for the OLS best fit line are calculated via bootstrapping). B: Point estimates of low/high stratum subsample estimates of commute disruption rate for the seven largest municipalities. C: Municipality-level average marginal effects of home stratum on the likelihood a user has their commute disrupted, with point estimates/95% confidence intervals estimated via logistic regression. Dashed vertical lines represent average effects across all municipalities.

Using a similar approach to that of the previous section, we examine whether higher stratum residents have more disrupted commute patterns (Fig. 5B-C). In the largest 4 municipalities, we find evidence ($p < .05$) that increasing stratum is associated with higher commute disruption probability. However, we only find significance at this level in only one other municipality, suggesting home stratum may play a less significant role in commute disruptions than on overall mobility reduction, particularly in smaller municipalities (the pooled marginal effect is 1.6%, $p < .01$). In these cases, other factors such as the type or
location of work may also drive commute disruption.

While our data does not reveal the industry or occupation of commuters, we can distinguish workers according to where they work. Broadly, commuters to wealthier areas fall into two groups: they might either work at more formalized, sophisticated firms or provide services to wealthier employers or residents. In the latter case, evidence from the US points to faster and more pronounced drops in spending among wealthier classes during the pandemic (34), corresponding to reduced demand for services in these areas. Here, we examine whether the stratum of a commuter’s destination is linked to the likelihood that they disrupt their commute. Specifically, we ask whether low stratum commuters experienced more commute disruptions when working in high stratum or commercial/industrial areas.

As expected, we find that the likelihood that a commute is disrupted depends considerably on the destination stratum (Fig. 6). We find a significant ($p < .05$) effect of destination stratum on the probability a commute is disrupted in 10 out of 22 municipalities, including 6 of the largest 7 municipalities. These results hold across the general population as well as for the subset of low stratum ($\leq 2$) commuters (coefficient estimates are displayed in Fig. 6A) - pooled marginal effects are quite similar for both cases (6.0% for all commuters, 5.7% for low stratum residents, $p < .01$ in both cases). We see this effect most clearly in Bogotá, where commutes terminating in stratum 5/6 are twice as likely to be disrupted as commutes to stratum 5/6 (Fig. 4B). These results demonstrate that both low and high income workers that commuted to high income areas were much likelier to experience disrupted commutes.

Digging deeper into the characteristics of the commute destination, we use administrative formal employment data to identify commercial/industrial centers in Bogotá (Fig. 6C). These correspond to zones with at least 20,000 formal jobs/km$^2$ (35). Generally,
these centers include a range of socio-economic strata, and include the central business
district (Chico-Lago) and the government (La Candelaria). Controlling for commute dis-
tance, we find that commutes to these centers were on average 14.3% ($p < .01$) more likely
to be disrupted while a 1-stratum increase was associated with a 10.2% ($p < .01$) increase
in the probability a commute was disrupted (point estimates in Fig. 6D). As above, we
find comparable effects when limiting our commuter sample to low stratum residents.

Hence, we find that higher income workers - with more tele-workable occupations
- were more likely to discontinue their commutes. However, we also observe a sharp
lockdown effect for work in higher income and more commercial locations. While we
would certainly expect high income commuters to stay home, the evidence points towards
a tendency for lower income workers who work in high commercial locations (presumably
in service-oriented occupations) to also stay home. Therefore, we observe a lockdown
“trickle down” effect - cities with higher income and more formalized firms not only have
more commute disruptions for high income workers, but also for low income workers.
This effect culminates in larger cities having higher levels of both commute and mobility
disruption, trends that are consistent throughout our findings.

5 Discussion

Previous work has shown that lockdown policies are successful at reducing mobility and
disease caseloads, using data from Europe (3) and China (2). Here we consider whether
the severity of the policy in terms of the share of people allowed out per day is correlated
with the size of the reduction in mobility. We found, in accordance with the previous
literature, that all cities experienced reductions in urban mobility - but there is no statis-
tical relationship between the severity of local lockdown rules and the degree of mobility
reduction. Larger, wealthier cities reduced mobility the most, even though they generally
Figure 6: Commutes terminating in wealthier areas and formal labor centers were more likely to be disrupted. A: Marginal effects of destination stratum on the likelihood a user has their commute disrupted across all detected commuters/in low stratum commuter subsamples (point estimates/95% confidence intervals estimated via logistic regression). B: Estimates of commute disruption rate in Bogotá for varying home/work stratum. C: Census-block characterizations of socioeconomic stratum in Bogotá, with the outlined regions representing formal employment centers - zones with at least 20,000 formal employees/km². D: Average marginal effects of commutes destination characteristics on the likelihood a commute is disrupted in Bogotá.
imposed less severe mobility restrictions. Smaller cities, with more informal employment, did not experience a comparable reduction.

While the signal linking city size and variables capturing local economic structure to mobility reduction is strong, there are a number of other factors which likely played a role. These include the degree of enforcement of the policy, the availability of economic aid to workers and firms, population density, and the number of infections in the city. For example, on a national level, the government provided cash transfers to informal workers and families before and during the study period (36), in addition to a host of economic relief measures (37,38). Future work might investigate further the role and distribution of aid in policies aimed at mobility restriction. Additionally, residents of cities with a larger caseloads early in the pandemic are likely to have been more willing to lockdown (39). Although further investigation is needed, we expect to find that (as with GDP per capita, formality rate and industrial complexity) these factors correlate with city size and are thus consistent with our findings.

Our findings highlight the role of labor structure in cities’ ability to reduce mobility. Less wealthy, often informal firms have less financial capacity to close operations. Workers at these firms are thus incentivized to continue working despite mobility restrictions. The example of Bogotá depicts this clearly - residents commuting to high income/formalized work areas were as much as twice as likely to disrupt their commutes (as compared to commutes to low income areas). This result is borne out even for workers from low income residential areas, suggesting that firm closures in these higher income/formalized areas affect both low and high income workers alike.

Our findings underscore the need for future policy measures to increase aid-based measures alongside or even in place of mobility restrictions. A large share of workers particularly in smaller cities - often informally employed and rarely in teleworkable occu-
pations - cannot work from home, and require substantial and sustained support. While wealthy economies, particularly those in Europe, have developed historically unprecedented wage support schemes, the ability of lower and middle income countries to sustain such schemes is limited. It may be possible to balance economic constraints under a ‘circuit break’ model (40), an emerging strategy that calls for (potentially repeated) short-term but severe mobility restrictions in order to manage caseloads within a fixed health system capacity.

References and Notes

1. S. Hsiang, et al., Nature 584, 262 (2020).

2. H. Fang, L. Wang, Y. Yang, Human mobility restrictions and the spread of the novel coronavirus (2019-ncov) in china, Tech. rep., National Bureau of Economic Research (2020).

3. S. Flaxman, et al., Nature 584, 257 (2020).

4. M. Sostero, et al., Teleworkability and the covid-19 crisis: a new digital divide?, Tech. rep., Joint Research Centre (Seville site) (2020).

5. M. Brussevich, E. Dabra-Norris, S. Khalid (2020).

6. G. Bonaccorsi, et al., Proceedings of the National Academy of Sciences 117, 15530 (2020).

7. S. P. Fraiberger, et al., arXiv preprint arXiv:2006.15195 (2020).

8. V. M. Carvalho, et al., Tracking the covid-19 crisis with high-resolution transaction data, Tech. rep. (2020).
9. J. Valentino-DeVries, G. Dance, *New York Times* (2020).

10. S. Caul, Deaths involving covid-19 by local area and socioeconomic deprivation: deaths occurring between 1 March and 31 July 2020, *Tech. rep.*, UK Office for National Statistics (2020).

11. C. H. Zhang, G. G. Schwartz, *The Journal of Rural Health* **36**, 433 (2020).

12. T. Lancet, *Lancet (London, England)* **395**, 1461 (2020).

13. G. Duranton, *Journal of Regional Science* **56**, 210 (2016).

14. N. O’Clery, A. Gomez-Lievano, E. Lora, The path to labor formality: Urban agglomeration and the emergence of complex industries, *Tech. rep.*, Center for International Development at Harvard University (2016).

15. C. M. Peak, *et al.*, *International journal of epidemiology* **47**, 1562 (2018).

16. H. S. Badr, *et al.*, *The Lancet Infectious Diseases* (2020).

17. N. Gozzi, *et al.*, *medRxiv* (2020).

18. E. L. Glaeser, C. S. Gorback, S. J. Redding, How much does covid-19 increase with mobility? evidence from new york and four other us cities, *Tech. rep.*, National Bureau of Economic Research (2020).

19. M. U. Kraemer, *et al.*, *Science* **368**, 493 (2020).

20. L. M. Bettencourt, J. Lobo, D. Helbing, C. Kühnert, G. B. West, *Proceedings of the national academy of sciences* **104**, 7301 (2007).

21. L. M. Bettencourt, J. Lobo, D. Strumsky, G. B. West, *PloS one* **5**, e13541 (2010).
22. D. R. Davis, J. I. Dingel, *Journal of International Economics* **123**, 103291 (2020).

23. J. Brinkman (2014).

24. J. A. Weill, M. Stigler, O. Deschenes, M. R. Springborn, *Proceedings of the National Academy of Sciences* **117**, 19658 (2020).

25. C. A. Hidalgo, R. Hausmann, *Proceedings of the national academy of sciences* **106**, 10570 (2009).

26. C. A. Hidalgo, B. Klinger, A.-L. Barabási, R. Hausmann, *Science* **317**, 482 (2007).

27. B. R. Roberts, *International Journal of Urban and Regional Research* **29**, 110 (2005).

28. Departamento Administrativo Nacional de Estadística (DANE), Censo nacional de población y vivienda, https://www.dane.gov.co/index.php/en/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018 (2020).

29. C. Medina, L. Morales, R. Bernal, M. Torero, *Economia* **7**, 41 (2007).

30. L. Lotero, R. G. Hurtado, L. M. Floría, J. Gómez-Gardeñes, *Royal Society open science* **3**, 150654 (2016).

31. J. I. Dingel, B. Neiman, How many jobs can be done at home?, *Tech. rep.*, National Bureau of Economic Research (2020).

32. M. Hatayama, M. Viollaz, H. Winkler, *World Bank Policy Research Working Paper* (2020).

33. T. Louail, *et al.*, *Nature communications* **6**, 1 (2015).
34. R. Chetty, J. N. Friedman, N. Hendren, M. Stepner, et al., How did covid-19 and stabilization policies affect spending and employment? a new real-time economic tracker based on private sector data, *Tech. rep.*, National Bureau of Economic Research (2020).

35. L. A. Guzman, D. Oviedo, J. P. Bocarejo, *Cities* **60**, 202 (2017).

36. J. Symmes Cobb, *Thomson Reuters Foundation* (2020).

37. M. Ravallion, Pandemic policies in poor places, *Tech. rep.*, Center for Global Development (2020).

38. M. Cárdenas, H. Martínez Beltrán, Covid-19 in colombia: Impact and policy responses, *Tech. rep.*, Center for Global Development (2020).

39. J. J. Van Bavel, et al., *Nature Human Behaviour* pp. 1–12 (2020).

40. Summary of the effectiveness and harms of different non-pharmaceutical interventions, *Tech. rep.*, UK Scientific Advisory Group for Emergencies (2020).

41. The authors would like to thank in no particular order YY Ahn (Northwestern University), Mohsen Bahrami (MIT Media Lab), Morgan Frank (University of Pittsburgh), Eduardo Lora (Harvard University), Juan Camilo Chaparro (Universidad EAFIT), Julian Cristia (Inter-American Development Bank), Jaime Alfredo Bonet-Morón (Banco de la República Colombia), and Carlos Alberto Medina-Durango (Banco de la República Colombia) for helpful discussion. SH and NO acknowledge support from the PEAK Urban programme, funded by UKRI’s Global Challenge Research Fund, Grant Ref: ES/P011055/1.