Mobility, Environment, and Inequalities in the Post-COVID City

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Abstract

The COVID-19 pandemic has brought about enormous disruption in mobility in cities We review and analyse the evidence generated since the advent of the crisis, paying special attention to travel behaviour changes and how they are hampering the achievement of sustainability goals. Modal shifts to more individual modes of transport, with regained interest in car usage, combined with the financial distress of public transportation and raising inequalities, appear as the most challenging problems city planners face if travel preferences do not revert shortly. We discuss policies and measures that could be implemented so that these risks are addressed and lessened.

Keywords: Covid-19; Mobility; Cities; Air quality; Inequality.

JEL Codes: O18; Q53; R11; R14.

Introduction

The COVID pandemic has brought about enormous disruption in many aspects of day-to-day life. The severity of social distancing forced the significant and widespread adoption of homeworking, the closure of a large number of business and the laying off a proportional number of workers (at best temporarily). Large cities experienced sharp mobility reductions Iio et al, 2021) and temporary improvements in environmental conditions during the initial months of the pandemic (Berman and Ebisu, 2020; Venter et al, 2020). However, the effects of Covid-19 are not limited only to that period but persist well beyond 2020. Indeed, both short-term and long-term consequences of COVID disruption augment some of the greatest challenges cities face, such as the fight against pollution and global warming, the financing of public transport and the promotion of a sustainable and safer mobility model.

Reduction in mobility has been particularly acute in collective transportation (UITP, 2020). Much-reduced ridership figures and imposed capacity constraints (Lozzi et al., 2020) have put metropolitan public transport systems finances under significant strain. Users' contagion risk perception has fuelled renewed interest in individual modes of transport, in preference over collective transportation services. As a result, effects on the decrease of collective transport demand have persisted after re-openings, imposing further stress on public transit finances. Homeworking acts as a land-use change facilitator (Ettema, 2010), making residence location less restrictive, with early evidence suggesting it can trigger moves to suburban locations (Su & Liu, 2020), increasing distance travelled and leading to higher car usage. All this has already translated into pollution levels returning

to pre-pandemic levels, whilst the economy has not yet recovered, which jeopardises many of the sustainability goals attained in past decades.

Additionally, the negative impacts of the pandemic have been larger in the most disadvantaged neighbourhoods, with low-income groups being more affected by layoffs, more exposed to infection (as a result of low telecommute compatibility) and being most reliant on public transport (Blundell et al, 2020; Dorn, Cooney and Sabin, 2020; Stantcheva, 2022). It is therefore difficult to disentangle the mobility, environmental and equality dimensions of COVID-19 impacts in cities.

Thus, the post-COVID city faces important challenges as a consequence of the interplay of these dimensions. Teleworking might decrease in the post-COVID city, but it will remain high by previous standards (OECD, 2021a; EP, 2021; Shutters, 2021), which could have significant effects on the distribution of trips between private car and public transport. Therefore, this implies that the formulation of appropriate policies will be needed to counterbalance any increased incentives for private cars and those detrimental to public transport are key in preventing environmental damage and to avoid further damaging the most vulnerable sectors of the population in the post-COVID city.

This paper contributes to the literature by providing a synthetic review of the evidence on the effects of the pandemic on mobility changes and its effects in cities. First, we cover the more immediate impacts produced by these changes (mobility, transit finances and environment). Then we review the evidence on mid- to long-term impacts, such as residential and firm relocations, as well as inequalities derived, both in the short term and in the long term. We intend to synthesize the broad but dispersed knowledge generated since the advent of the pandemic around this issue and discuss, with prospective analysis,

how the post-COVID city and its challenges might look like in the future, and how current and future policies might interact with them.

The remainder of the manuscript is organized as follows. First, we cover the evidence on mobility changes during the initial phase of the pandemic. Then, we review the consequences on the finance of public transportation, as well as on air quality. We next analyse the evidence on the link between teleworking and mobility, which is the causal nexus via residential relocation. Thereafter we discuss equity concerns. Finally, we discuss how the evidence provided in all these spheres shape or affect the challenges of the post-COVID city. We conclude with some final remarks.

Mobility changes during and after the crisis

The pandemic has produced significant shocks on mobility in cities (and their surrounding areas); first due to restrictions imposed by public authorities, and later due to its effects on citizens' perception and preference. Thus, the analysis of mobility changes must distinguish two main phases. The outbreak of the crisis with the impact on mobility produced by policies aiming at reducing infection risk, and mobility changes that came about after the reopening and reestablishment of a certain normality, the so-called 'new normal'.

Regarding the first phase, evidence shows that cities experienced sharp mobility reductions following outbreaks due to the public authorities introducing containment measures such as closing schools and workplaces, cancelling public events, imposing restrictions on gatherings and travel, and the use of public transport to limit the spread of the virus; with curfews or lockdowns being the most restrictive measures. According

to UITP (2020) there were decreases in overall urban mobility demand of up to 90% during lockdowns in Europe, with decreases of 40-70% continuing during the recovery period in May-June 2020. According to google mobility trends, the lowest point was reached in April 2020 (-76% public transportation, -65% traffic, walking -67%) (Lozzi et al., 2020).

Several of these measures specifically targeted mobility due to its high correlation with Covid-19 outbreaks and deaths; it is linked to social interactions and risk-of-exposure factors. Specifically, transit authorities in many cities translated social distancing measures into public transport by a number of mechanisms. They have variously encouraged public transport usage only by essential workers, introduced rules for keeping distance between passengers, enforced mask wearing, applied capacity restrictions, reduced the number of services running and some routes were shut down during the worst outbreaks.

This has likely heightened consumers' risk-of-infection perception, already high since major outbreaks, as they associate publica transport usage with the presence of many people in enclosed spaces where it is difficult to ensure proper social distancing. Early evidence, gathered during the first waves of the pandemic, suggest that fear-of-infection is one of the key reasons to choose a specific transportation mode (McKinsey, 2020; IBM, 2020), with people specifically reducing travel to locations perceived as risky and avoiding public transit (Hotle et al., 2020).

This fuelled a renewed interest in individual modes of transport, with a modal shift towards private car journeys in metropolitan areas all over the world, both in developed countries (Basu and Ferreira, 2021; Beck and Hensher, 2021a, 2021b) and in developing

countries (Dai, Liu and Li, 2021; Thombre and Agarwal, 2021). Decreases in overall mobility were accompanied by an increasing share of private mobility, as people seek to maintain social distance during journeys (UITP, 2020). In June/July 2020, with the reopening of most regions, private mobility re-established, and early evidence shows that, in most European countries, the levels post-COVID are higher than in January/February 2020 (Palomba, 2020).

The Boston Consulting Group ran a wide survey to 5000 residents of major cities in the US, China and the largest countries in Western Europe (Bert et al., 2020). Interestingly, they found the modal effects in the first lockdown were remarkably similar in all these countries. Regarding expectations for the post-lockdown short term, respondents in all cities showed an intention of less frequent use of public transportation and more frequent use of private cars and biking/walking. These expectations were demonstrable in all cases, and particularly acute in China for both public transportation and private cars. In a similar vein, Beck and Hensher (2021b) confirm that rebound of transit after the initial COVID waves has been higher for private car than for other modes, with an overall increase in the modal quota of private car and walking and decrease of collective transportation (Beck and Hensher, 2021a).

Looking at the evolution of public transport and car driving throughout 2020 (Figure 1) in five European cities, driving figures consistently recover faster and remain above public transport even when going back to 'normal'.

(Insert Figure 1)

Figure 2 provides an analysis of the average difference in demand during lockdowns, reopening of society, and 'new normal' phases, with respect to pre-pandemic baseline. A

cross-comparison of these cities suggests that peoples' fear-of-infection might be still high but also that implemented policies might play a big role on the post-Covid mobility.

(Insert Figure 2)

At local level, the trend towards individual mobility has been also spurred by social distancing measures and public transportation restrictions during lockdowns. This heavy decline of mobility supply within the city had to be solved by citizens to cover their mobility needs, even at a hyper-local level. For this reason, the pandemic has produced a surge of micro-mobility options, which became highly competitive with respect to other alternatives and safer from contagion, with walking and biking use the modes travellers report to be willing to lean on more going forward. Fear of public transit, increased bike infrastructure, subsidies/rebates and other stimulus measures, and its leisure characteristic, are all behind this surge. As a result, many cities increased their cycling infrastructure even with pop up bike lanes (i.e., Berlin, Paris, Brussels, Lisbon, etc.). On the contrary, companies of shared vehicles (cars, bikes, scooters, etc.) and private mobility services had to halt their services (Lozzi et al., 2020).

Public transportation under financial strain

Significantly reduced ridership figures and imposed capacity constraints have put metropolitan public transport systems finances under strain. Social distancing measures (e.g., keeping a minimum distance between passengers, reduction of capacity ratios, forcing passengers to wear protective equipment) attack the very core reasons that justify public transport subsidies. First, they eliminate the ability of transit to exploit economies

of scale, where capacity reductions imply unfeasible fleet expansion and enormously increase the need for subsidies (Basso, Sepúlveda & Silva, 2020). Second, they reduce transit systems' ability to exploit the positive externality of increased ridership that justifies extra services that reduce both riders time cost and the operator operational cost (Mohring, 1972). And third, the ability of metropolitan public transport systems to correct unpriced external effects of car traffic is reduced (Anderson, 2014; Adler & van Ommeren, 2016).

Financial distress is a growing problem worldwide. For instance, according to EBP (2021), transit ridership in 2020 dropped by 79% in the US, compared to pre-pandemic levels, and ridership from June through December 2020 remained about 65% below pre-pandemic levels. Despite relief funding provision, gaps in funding continue to grow due to low ridership, and with it both fare and tax revenues. Depending on the scenario of ridership return, EBP (2021) estimates funding needs between $37.4 billion to $41.3 billion. The same situation applies in Europe, with lockdowns reducing public transport ridership by 90% throughout the continent.

According to the UK's government statistics (https://www.gov.uk/government/collections/bus-statistics), in London's metropolitan area the quarterly passenger journeys by local bus between January and March 2021 were just the 39% of the journeys made in the same months of 2019. The same percentage applies in the rest of UK metropolitan areas, and it is even lower in other UK non-metropolitan areas (33%). Figures for London's underground network are also stark. Journeys made in August 2021 were just at 22.5% of those made in August 2019. This creates an significant financial deficit in the aftermath of the pandemic, likely putting

transit authorities' budgets under big strain. Transport for London, for instance, estimates that fares revenue was cumulatively around £2.4bn lower in 2020 than it would have been prior to the Covid-19 pandemic (https://www.london.gov.uk/questions/2020/4671#a-192490).

The environmental consequences of mobility changes

The major silver lining that came out of the pandemic is the improvement in air quality that followed lockdowns instituted to contain the virus spread. Evidence on such reductions is mounting, even if the magnitude of the effect varies depending on the specific pollutant considered, the empirical method applied, how they control for potential confounders and the time window of analysis.

Studies conducting simple before-after comparisons generally report high reductions in pollutants concentration. Berman and Ebisu (2020) show a reduction of around 25% in nitrogen dioxide (NO_2) and 5% particulate matters 2.5 *(*$PM_{2.5}$) in urban areas comparing outbreak periods with respect to pre-pandemic figures in the US. Reductions are also reported globally ranging from 25 to 70% in NO_2 using satellite data (tropospheric monitoring instruments), as in Venter et al. (2020). These results are consistent with the figures reported by studies using ground-level monitoring stations station (e.g., Tobías et al., 2020).

Studies attempting to explore the causal effects of lockdowns on air quality also report a wide variation on their estimated results, although reported pollution reductions are lower at an aggregate level. For example, He et al. (2020) and Liu et al. (2020) find

reductions ranging 6-38% depending on the specific pollutant based on difference-in-differences estimates comparing cities with and without lockdown measures. Using synthetic control techniques, Cole et al. (2020) estimates a reduction of around 60% for both NO_2 and PM_{10}, with no discernible impact in sulphur dioxide (SO_2) and carbon monoxide (CO). Based on a regression discontinuity design method and satellite data, Dang and Trinh (2021) estimate a 24-32% reduction in NO_2 after lockdowns.

Interestingly, evidence indicates that the reduction of nitrogen oxides (NOx) is followed by an increase in Ozone (O_3) levels. This implies that the sizeable welfare improvement derived from avoided non-Covid mortality (Chen et al., 2020; Dang and Trinh, 2021; Liu et al., 2021), can be partially offset by the trade-off between pollutants (Achebak et al., 2021).

It has long been established that air pollution levels can affect the severity of respiratory illness, given their link with chronic inflammatory responses that can aggravate acute respiratory syndrome caused by Covid-19. Based on regional data, researchers find evidence of a positive correlation between Covid-19 cases and air pollution in the UK (Travaglio et al., 2021), Italy (Fattorini and Regoli, 2020), Germany (Isphording and Pestel, 2021), and France and Spain (Ogen, 2020). However, the causal link has not been accurately quantified yet, as previous studies do not control all potential confounding factors affecting both virus transmission and pollution levels (see Riccò et al., 2020; Cole et al., 2020). In any case, without individual data that allows controlling for a wide range of individual characteristics, such evidence will remain inconclusive, at least about its true magnitude.

By using on ground-level monitoring station data, we offer a raw comparison of pollution levels pre- and post-lockdowns in the several large cities in Europe. We estimate how the median daily concentration level of traffic-related pollutants do change with the period considered compared to pre-pandemic ones, as described in Table 1. Our results show that lockdowns tended to reduce pollution in general, yet the magnitude is city and pollutant dependent. PM_{10} reductions have generally faded away after societies reopened, with the 'new normal' looking pretty much the same as the old one in terms of average daily concentration levels (no statistically significant difference). NO_2 levels are still well below the pre-pandemic levels, even important setbacks in some cities. Conversely, O_3 tended to increase during lockdowns and stayed higher whenever NOx fell (as it acts as a quencher of the former), showing a trade-off between pollutants.

(Insert table 1 here)

The transience of the air quality gains, which have mostly returned to pre-pandemic levels even though the economy is not fully recovered, is a warning sign of the undesirable consequences of the shift towards individual mobility and the increased appeal of cars. Public managers and policy makers that are responsible for metropolitan environmental conditions might need to redouble their efforts to revert this trend in the post-Covid city.

Teleworking as a trigger of new mobility patterns

Although the prevalence of telework varied strongly across industries and occupations, one of the labour market outcomes of the pandemic –with mobility consequences- has

been a generalized increase in remote work, that persists beyond the forced measures of confinement and mobility restrictions (Eurofound, 2020; Okubo, 2020). For instance, with respect to 2019, teleworking more than doubled in France and nearly doubled in the UK, whereas in Italy it increased more moderately, by 15 percentage points (OECD, 2021b).

Teleworking might trigger land-use changes, as it diminishes transportation costs (commuting costs) and increases workers' disposable income (if salary remains unchanged). As result, workers can afford longer commutes when they are necessary (despite being less frequent) and enjoy higher utility levels by increasing their housing consumption at locations further away from workplaces (with perhaps cheaper housing prices or better quality of life). This will make central locations comparatively less attractive, also affecting the housing market and partially easing gentrification in central city districts.

The relationship between the growth of work-from-home and residential location was suggested some time ago (e.g., Ettema, 2010). In this vein, early evidence in the US housing market during the outbreak of the pandemic showed a decline in the demand for housing in cities and areas with higher population density, with no significant difference in new listings (Su & Liu, 2020). Interestingly, the decline was larger in neighbourhoods with more homeworking-compatible jobs.

This residential relocation effect was early indicated by Florida, Rodríguez-Pose and Storper (2021), suggesting that Work-From-Home leads to higher degrees of suburbanization of highly educated, high paid families. Because of this trend, Nathan and Overman (2020) emphasize that suburbs benefiting at the expense of the city centres is a plausible outcome of the pandemic. Subsequent empirical research, mainly conducted

in the US, has revealed important effects in that regard. Delventhal, Kwon and Parkhomenko (2022) analysed the effect of increased work-from-home in the metropolitan area of Los Angeles and find two main effects regarding location and travel. First, residents move to the periphery while jobs move to the core; second, both travel times and traffic congestion decrease. Brueckner, Kahn and Lin (2021) found that work-from-home encouraged the relocation of workers to cheaper locations while preserving their jobs.

Inequality

The Covid-19 pandemic has had particularly acute effects on the most disadvantaged segments of the population, both at a broad societal level (Dorn, Cooney and Sabin, 2020), as well as at the local community level (Deslatte, Hatch and Stokan, 2020). The pandemic has increased income inequalities (Aspachs et al., 2021) and its major legacy might be its long-term increase (Blundell et al, 2020).

Negative impacts have concentrated in most disfavoured areas, with economic and social conditions being a major determinant of Covid outbreaks (Hamidi, Sabouri, & Ewing, 2020). Residents of such neighbourhoods are generally employed in the sectors more disrupted by social distancing measures. Simultaneously, inadequate housing conditions, high household crowding, the lack of economic means to properly isolate and low homeworking-compatibility also made them more exposed to infection. Moreover, the fact that they tend to experience longer average commute times due to the mismatch between job and residence location, while being more reliant on public transit, also made them disproportionally affected by transit services cuts. Finally, for several cities, lower-

income groups tend to reside in areas with higher air pollution levels (Hajat et al., 2015), showing the relevant interlink between mobility, environmental and inequality dimensions of Covid-19 impacts.

One of the factors that have accentuated inequalities during the pandemic has been the extension of work-from-home and its uneven distribution among different types of workers (Stantcheva, 2022). First, effects on unemployment have been less acute for occupations for which work-from-home was more feasible, while occupations less suited for work-from-home have borne more unemployment and wage reductions (Adams-Prassl et al, 2020; Garrote Sanchez et al 2021; Gottlieb et al., 2021). The problems of mobility adaptation of low-income travellers had important consequences in terms of their risk exposure due to commuting. As result, individuals from higher per-capita income areas had larger mobility reductions than people from lower per capita income zones during lockdowns (Iio et al, 2021). Consequently, differences in work-from-home have exacerbated inequalities both within countries and between countries (Adams-Prassl et al, 2020; Palomino, Rodríguez, and Sebastian, 2020).

The post-COVID mobility: expectations, challenges and policy measures.

Despite the heterogeneity of cities and their different response and resilience to Covid-19 shocks, this section discusses plausible trends supported on the evidence reviewed. Note that the literature has focused particularly on big cities as case studies, with most prominent cities in countries' urban hierarchy as referent objects of study. Thus, expectations, challenges and policy measures considered and discussed below are mainly

devoted to large urban agglomerations, where most mobility challenges and spillovers are more striking. This might not be always representative of the context, necessities, and trends of medium size urban settlements, due to different paths followed with city size or due to different economic, social, demographic and geographical structures.

A more individualistic mobility

The evidence reviewed above points to a likely trend of increased individual mobility modes of transportation. In the short distances (mainly urban mobility), it means a likely increase of the number and usage of micro-mobility and personal vehicles such as bikes, segways and scooters, where walking is less attractive whatever the reason (distance, safety, physical conditions, etc.). City planners may take this as an opportunity to rethink the urban space and existing urban infrastructure, especially if we take into consideration that about one-third of the European population travels daily less than 10 km. Cities must prepare to digest this modal shift and displaced trips in form of individual mobility options. Temporary solutions and improvised infrastructures (i.e., tactical urbanism) must be reconsidered to provide permanent solutions in coordination with other modes' needs and restrictions.

Public transport: relieve and relaunch to reverse the coming motorisation wave

This increase, which would seem to move cities to an apparent more sustainable model, has as a counterpart that most of this micro-mobility demand used to travel by public transportation. As result, it damages the financial sustainability of the cities' public transportation, and other sources of revenue must be found to retain services without creating huge financial deficits. Moreover, it also may mean an increase of powered two-

wheelers and car usage, the later particularly in interurban mobility, i.e. Metropolitan mobility, which would undermine the finance accounts of both urban and interurban public transportation, and would worsen the sustainability of the mobility system.

A pool of surveys on future mobility intentions for a variety of countries collected by Arthur D'Little Lab for UITP (2020) suggests that changes in mobility preferences will remain. Car usage is expected to increase significantly according to the surveyed respondents, between +10% and 94% (only a Belgian survey shows a negative figure on the future car usage, -13%). At the same time, surveys indicate a marked decline in public transportation ridership (between -23% and -43%), as well as the increase of walking and cycling (up to 50%) and a decrease of shared mobility options (up to -50%).

No doubt, in the long term, public transportation will recover its attractiveness if policymakers want to reverse this trend (Bert et al. 2020) and thus are willing to raise budgetary contributions. Meanwhile, continuous financial support will be needed, as well as reinforced collaboration between local, regional and national administrations to guarantee the feasibility, attractiveness and safety perceptions of public transportation.

A new scenario for public transport did commence in 2021, with the mass vaccination phase. Our quantitative analysis does not take the vaccination phase into account however, since mass vaccination did not begin before late December 2020. The generalized adoption of vaccines may also affect commuting behaviour and future mobility trends. According to a recent study by Andersson et al. 2021, vaccinations will prompt reductions in voluntary social distancing and adherence to hygiene guidelines. This may induce the return of mass transportation travellers. Zhong, Wang and Day (2021) estimated that one-percentage-point increase in the vaccination rate led to a

0.67% increase in the mobility in public transit centers. But this increase in ridership can bring about higher viral transmission. These results imply that existing policies regarding social distancing might be less effective as vaccines are deployed, and governments might need to apply stricter policies when needed.

Some governments, additionally, have started to demand proof of vaccination by their passengers, which might be a new tool to regain the confidence of passengers of mass transportation systems in the safety of public transportation (Shuetze, 2021). A similar pattern has been observed in many European countries (e.g., Germany, Spain, Italy, and France), regarding the requirement of certificates of vaccination (*COVID passes*) for other social activities, often related to mobility. For instance, since late 2021 COVID passes were required to enter restaurants and other hospitality facilities. Requesting Covid certificates significantly increased vaccination rates in France, Germany and Italy, and the positive effect on GDP growth was significant as well (Oliu-Barton et al., 2022). Therefore, although no estimation was done for the effect of COVID passes on mobility, it seems that is likely to have been positive. However, any potential effect of such restrictions on associated metropolitan mobility, if any, will not last long, as requirement for COVID passes have been progressively withdrawn during 2022 (January in Spain, March in Germany and France, and May in Italy).

Additionally, new trends like homeworking need to be considered, as they may result in fundamental shifts in transit authorities' revenue streams. An example of this is the increased uncertainty of the number of trips commuters will take per week (or month) with increased work flexibility and homeworking. This is likely to shift them towards more

flexible multi-ticket options that do not imply big upfront spending, stressing the need to take advantage of the pandemic to rethink fare schemes.

Similarly, other sustainable mobility innovations, such as shared and pooled mobility options, will need to regain the confidence of travellers after the pandemic. Given this setback that impacted a flourishing industry, local authorities might study collaborative arrangements with these entities that, although in the spirit of lure, contribute to the reduction of negative externalities and spur innovation and social dynamism. No doubt diversified and innovative cities are in a better position than other urban economies that heavily rely on classic industrial and service-oriented sectors –such as tourist destinations.

Incentives set to favour car ownership and its use

Although car sales plummeted during the lockdown, the pandemic has set the incentives that make cars more attractive, partially offsetting the efforts made recently by city planners to disincentivise car ownership and use. Private mobility has expanded during the pandemic, as they offer protection against contact with other travellers. Further, fluent traffic during lockdowns allowed faster commutes, increasing the perception of relative attractiveness with respect to other forms of mobility, such as public transportation. According to surveys, between 17% and 40% of respondents intend to use more often their cars, with 25% reporting using it as their exclusive transportation mode going forward (Bert et al., 2020; IBM, 2020). This is likely to translate into increased car ownership. Nonetheless, evidence suggests that car purchase intent is on average still below pre-pandemic levels (about 10% lower) but has increased especially among high-income households with less focus on electric vehicles, except in China (McKinsey, 2020). Indeed, some reports expect consumers' purchase intentions to be less focused on

electric vehicles (EVs) going forward due to the pandemic effect on preferences (McKinsey, 2020), but this assertion might be premature. The IEA (2020) suggests lower impacts, given that their estimates indicate that the demand for EVs has been less impacted than other car segments due to their benefits, subsidies and tax reductions. In any case, authorities should pay attention to these preferences and implement countermeasures for more efficient and sustainable private mobility.

The increase of planned purchases is, however, evident since the first wave (McKinsey, 2020). Bert et al (2020) suggests that around 10% of EU respondents are more likely to buy a car post-lockdown, regardless of their income group. However, these figures show large geographical disparities, larger for the US and huge for China, with ranges of 30-20% for high-income and 80-40% for low-income groups. Whether car ownership rises or not will be decided by the balance of the appeal of cars compared to the financial constraints and disincentives implemented by cities. Furthermore, the dynamics of oil prices will also influence car ownership and ridership. Brent prices have significantly increased after Spring 2020 (pandemic peak) and have increased further after the invasion of Ukraine by Russia on February 24th, up to a level not seen since 2014. It seems clear that a disincentive to private ownership and car usage would emerge were prices to stay at the level they have achieved by Spring 2022.

The longer the pandemic persists, the more probable it is that vehicle ownership will increase for high-income families and those with greater adaptability to moving or changing their occupations or job locations. In any case, closely monitoring the car sales market might be an effective anticipatory strategy for city planners to predict their motorisation levels and the need for countermeasures.

Even if the potential growth of congestion and the dynamics of oil prices could somehow contain the incentive to increase car usage, city planners must be aware of the potential risk of increased private cars usage and make use of their travel demand management toolkit, considering the options most able to influence the modal choice decision (congestion tolls, parking regulation and fees, etc.) with the advances made in information and communication technologies and actions that favour and sustain an accelerated transition towards more efficient and sustainable motorisation (electric cars, shared vehicles, other forms of Mobility as a Service -Maas- and Logging as a service -Laas-, etc.).

Teleworking as an additional driver of motorisation?

Existing evidence on the persistence of increase in work-from-home in the post-COVID era, whilst preliminary, suggests that the trend to increase in work-from-home has accelerated (Beck and Hensher, 2021a), as the most valued benefit is not commuting (Beck and Hensher, 2020). Thus, an increase in the level of homeworking will be permanent (Davis, Ghent and Gregory, 2021; Mertens, Blandin and Bick, 2021), and it may well be the only long-term change emerging in the post-pandemic city (Beck and Hensher, 2021b). A recent study for the US by Barrero, Bloom and Davis (2021) conducted large surveys on work-from-Home and found that less than 30% of respondents intended to return to pre-Covid activities, and the percentage of labour satisfied by remote workers in the US will be 20% of the total, five percentage points above the pre-pandemic levels. This trend is also found in recent official estimations made by the Bureau of Labor Statistics (BLS); comparing pre-COVID BLS's original projections of long-term impacts from several disruptive trends on the labour force of 2029 with projections made for 2029

after adjusting for COVID disruption shows that the adoption of teleworking will likely accelerate after the pandemic (Shutters, 2021).

In Europe, the Eurofound (2020) survey suggests that teleworking is losing some traction after the peak of COVID crisis. In early 2021 remote working is less prevalent than in the summer of 2020, particularly in the worst-hit countries by the crisis. For instance, in Spain teleworking rate dropped 2.5 percentage points, from 19.1% in the peak of COVID crisis (2T 2020) to 16.6% in the first trimester of 2021. That notwithstanding, the 2021 figure was double than that in 2019: 8.3% (Randstad Research, 2021: 23). Whilst the increase of teleworking overall in Europe may be less acute than that in the US, recent studies indicate that "Workers wish and managers expect telework to remain quite widespread after the pandemic (albeit less so than during the crisis)" (OECD, 2021a:1), and that teleworking in post covid will be significantly higher than before the pandemic, although part of the expansion can come from hybrid forms of teleworking: not full time, but rather a proportion of days in the week (EP, 2021). Indeed, the actual expansion of teleworking after the COVID crisis will not be fully assessed until after the pandemic is over, as positive effects on productivity from the COVID shock are not yet firmly established (e.g., Gibbs, Mengel and Siemroth, 2021). However, existing data and projections suggest that the post-covid city must consider the consequences of higher teleworking rates.

Increased car usage outcomes might seem to be offset with teleworking because this might decrease mobility demand. However, note that Beck and Hensher (2021b) point to the likelihood of increased private cars use, predominantly for commuting, as commuters that were previous users of public transport might be more willing to incur congestion and parking costs if they are incurred in a smaller number of days during the week.

Although less frequent, working from home is expected to favour longer trips. These longer commutes combined with more flexibility in working hours might increase interest in individual vehicle use, as holding all the other things equivalent, private mobility offers more attractive travel times in such a situation.

The evidence reviewed above about teleworking as a relocation trigger suggests a structural change in home buyer's preferences, at least temporarily, where dense areas, usually central city districts, lose relative appeal in favour of more peripheral areas -even municipalities- with higher quality of life levels but with longer commuting times. The evidence from the UK before the pandemic, already suggested that those that work from home more frequently have longer commute in terms of distance travelled but shorter total travel times (Melo and de Abreu e Silva, 2017). This is expected to be the case of higher-income families and of workers in industries/jobs where working from home occurred during the pandemic and is set to continue albeit only partially in some jobs.

Whether this is a tipping point in the previous trend of residents seeking accommodation in central locations and gentrification consequences, will depend on how long the relative strengths of the forces shaping consumers' choices is disrupted by the pandemic. Note, however, that housing is a durable good, and its purchase is only considered few times in a lifetime for specific time windows. Those confronted with the current set of incentives are the ones for whom residence location choice is more affected. Near-centre municipalities with amenities and higher quality of life levels will likely face most of this relocation pressure in the coming years, a situation that may be reversed if this pandemic ceases and other sets of consumers, in a different context of incentives, engage with the housing market.

Likewise, this may also apply to firms' relocations (see Tayyaran & Khan, 2003), especially for firms for which the workforce is not constrained to daily on-site jobs. Then, work-from-home allows firms to expand their potential labour market overcoming local constraints. This might pull firms towards central locations with higher exogenous productivity due to agglomeration effects (depending on the industry) but may also push them away to less central districts to access lower rents and workers' commuting compensations. Nonetheless, if there is a residential relocation towards the suburbs, it could create a cost incentive for firms to relocate in the opposite direction, due to lower office prices, which is further exacerbated by the higher cost-efficiency of central locations thanks to the saving in floor space as a result of a proportion of homeworking. The most likely beneficiaries of these effects would be those firms with higher real estate costs and high wages, given that they will be the ones pursuing more telework adoption. Some theoretical works suggest that job centralisation (or some sort of polycentrism) is a plausible result if no offsetting congestion effect on commuting times occurs (Delventhal, Kwon, & Parkhomenko, 2022; Lennox, 2020).

Covid19 as an additional source of growing inequality

The pandemic has hit the lowest-income sectors of society most severely, and therefore, the poorest and most vulnerable neighbourhoods will need special attention by local policymakers. Regressive effects from both the pandemic and the implementation of travel demand management tools to fight motorisation, such as parking fees and congestion charging, can be partially offset by the dedicated allocation of revenues to measures aimed at improving lower-income neighbourhoods and their mobility (benefit districts). Indeed, because lower-income travellers are intensive users of public

transportation, revenues generated can serve to aid current public transportation financial needs assisting the budgetary burden.

The mobility changes described in this paper have important implications in the land-use dynamics in metropolitan areas as well. It is not a new phenomenon, as car-oriented infrastructure developed in the past allowed wealthy residents to relocate to the suburbs and still rapidly reach their jobs in central locations (Baum-Snow, 2007) until the increase in congestion and negative externalities mitigated some of the advantages. Subsequently, the shift towards service industries, agglomerations economies and the revitalization of city centres spurred the back-to-the-city gentrifying movement. Actual cities show a patchwork of high- and low-income areas as a consequence of such back and forth dynamics, mostly driven by the residence location decision of the wealthy, who tend to locate in the most desirable places (high in amenities) while the less-advantaged are pushed towards distressed neighbourhoods, fringe zones and the periphery (Florida & Adler, 2018).

The boost in homeworking will largely affect high-income workers, being less limited by constraints on employment location, allowing them to relocate to high-amenity areas farther away from their jobs. This can be expected to slightly tip the scale towards a less intensive housing prices pressure for central locations spreading out to high-amenity municipalities in the metropolitan area and its surroundings. Additionally, given that low-income groups will be the ones facing larger income reductions in the aftermath of the economic crisis, this can be expected to trigger residential relocation towards more affordable areas, further widening the disparities between neighbourhoods.

The economic crisis might have implications from a land-use perspective too. The drop in fiscal revenue and large expenditure for cities will result in sizeable fiscal deficits (CEMR, 2020). This will hinder the provision of public services, further reducing the amenity effect of low-income urban areas and accessibility levels if those cuts affect public transit provision. This might further increase the gap between job and residence location, which can be at least partially alleviated by transport subsidies (Martin, 2001).

Finally, it is worth taking a broader view on more general trends of inequalities in the post-pandemic city. The impact on income inequalities from the intense COVID disruption was initially alleviated, in some countries, by the support programs implemented in 2020 to mitigate income loss and dislocation. In this way, post-tax income inequality in 2020 decreased in the US (Buckley, Barua and Samaddar, 2021) and several European countries (Clark, d'Ambrosio and Lepinteur, 2021). However, the recovery of the labour markets has been more intense, thus far, in higher and medium paid occupation than in lower paid occupations (Buckley, Barua and Samaddar, 2021), which could again widen income inequalities. Furthermore, supply constraints and inflationary processes (if these are not transitory) may further damage conditions for low skilled jobs and the weakest social strata, generally.

Should these trends persist in the post-covid economy, inequalities between neighbourhoods in the post-covid city (and between cities as well) would be aggravated. This would call for active social policies (beyond those specifically related to public transit and mobility discussed above) oriented to prevent sharp widening of income gaps and the deterioration of the social fabric in the most disadvantaged urban neighbourhoods.

Concluding remarks

Cities are dynamic social entities that evolve and adapt systematically. The Covid-19 pandemic has brought a new shock to these cities that has had, and will continue to have, a lasting effect with consequences on existing challenges. Among them, the achievement of sustainable mobility targets might be hampered by the disruptive effects of the pandemic and its effects on travel behaviour.

We have reviewed the evidence on how mobility has changed and some of its consequences: public transport financial distress, air quality potentially worsening and increased inequalities. Moreover, we discussed how social and labour consequences of the pandemic, such as the rise of homeworking, have impacted how we move and where we live, indirectly influencing the rest of the outcomes mentioned as mobility change impacts.

An open question that we cannot answer is whether these changes will remain, and to what extent, in the long run. In any case, one of the most striking challenges for city planners will be the relaunch of public transportation and other initiatives promoting sustainable mobility (i.e., Maas and Laas services) and the management of increased private vehicle demand. Therefore, city planners will need to carefully follow to what extent these effects remain in the post-Covid city and be ready to act with a menu of available and studied measures.

This paper might also suggest further lines for future research. Most available evidence refers mainly to big cities, which are heterogeneous in several important aspects – such as urban, economic, and sociodemographic structures. Thus, future research considering the role of these heterogeneities on less populated cities will be of great interest.

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Table 1. Comparison of median daily pollution levels between lockdown, reopening and new normality with respect to the pre-pandemic period (Jan 2018 to Dec 2019).

Pollutant	Period	Barcelona	Madrid	Paris	London	Amsterdam
PM_{10}	Lockdown	-35.0%	-23.7%	-6.8%	n.s.	-12.2%
	Reopening	-35.4%	-24.4%	-33.8%	n.s.	-12.5%
	New normal	-6.2%	-23.8%	n.s.	n.s.	n.s.
NO_2	Lockdown	-60.2%	-48.7%	-32.6%	-24.2%	n.s.
	Reopening	-51.5%	-48.4%	-28.0%	-32.5%	-28.1%
	New normal	-28.8%	-33.6%	-16.6%	-24.7%	-36.5%
O_3	Lockdown	14.7%	44.5%	14.1%	40.2%	n.s.
	Reopening	n.s.	17.7%	17.2%	39.3%	34.6%
	New normal	n.s.	24.1%	n.s.	34.1%	12.0%

Note: Estimates are obtained by running city-specific log-linear regression models using the log of daily mean pollutant concentration levels at ground-level monitoring stations (dataset available at the Air quality Open Data platform - AQICN) and dummies for each pandemic period based on restrictions set in place in each given date (pre-pandemic period used as the base category). All models include controls for weather conditions (wind speed, temperature, pressure, humidity, and their quartic polynomials), and time-specific effects related to the week of the year and day of the week to account for seasonal patterns. Further details on the econometric procedure are available upon request. n.s.: Nonsignificant

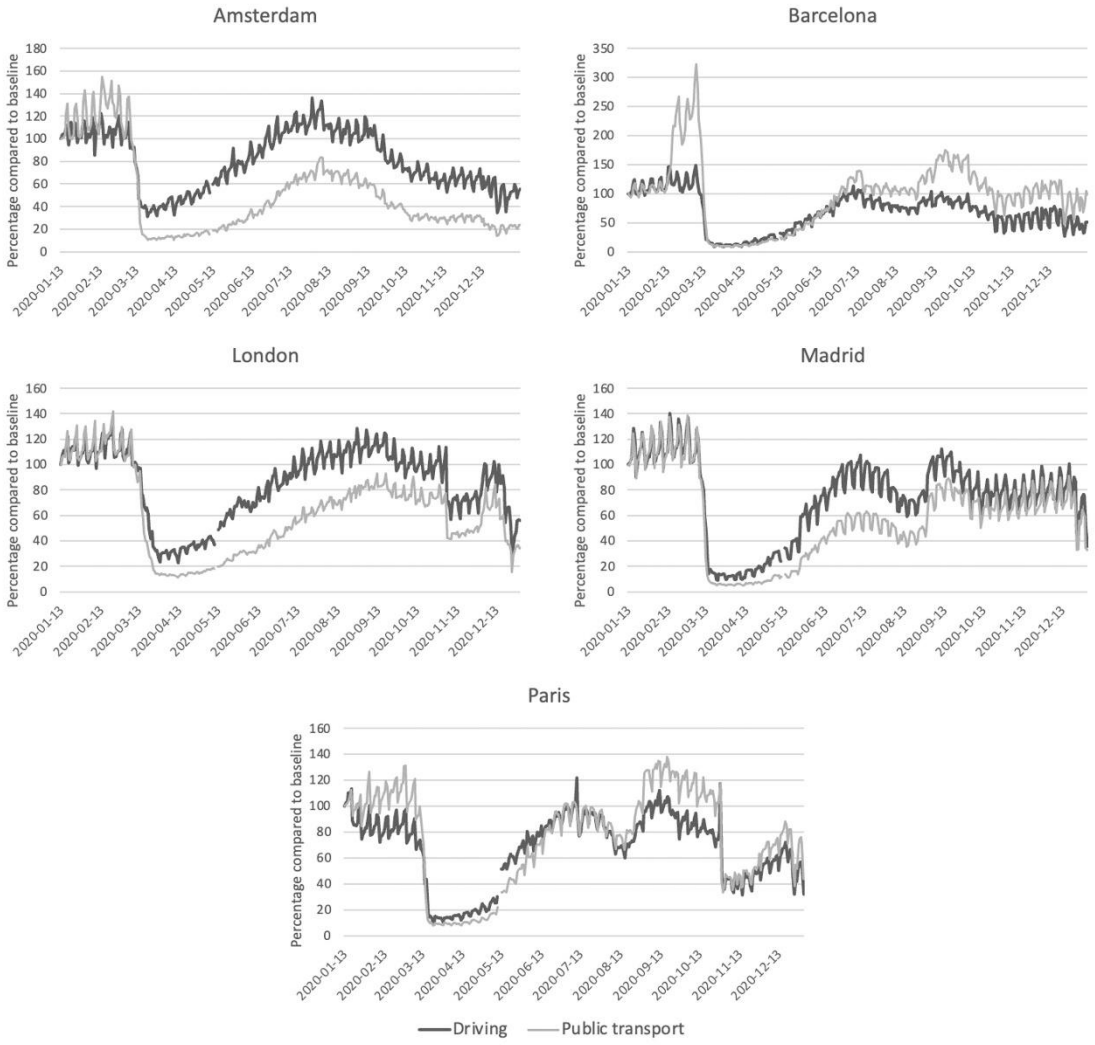
Amsterdam
Barcelona
London
Madrid
Paris
Percentage compared to baseline
Driving
Public transport

Figure 1

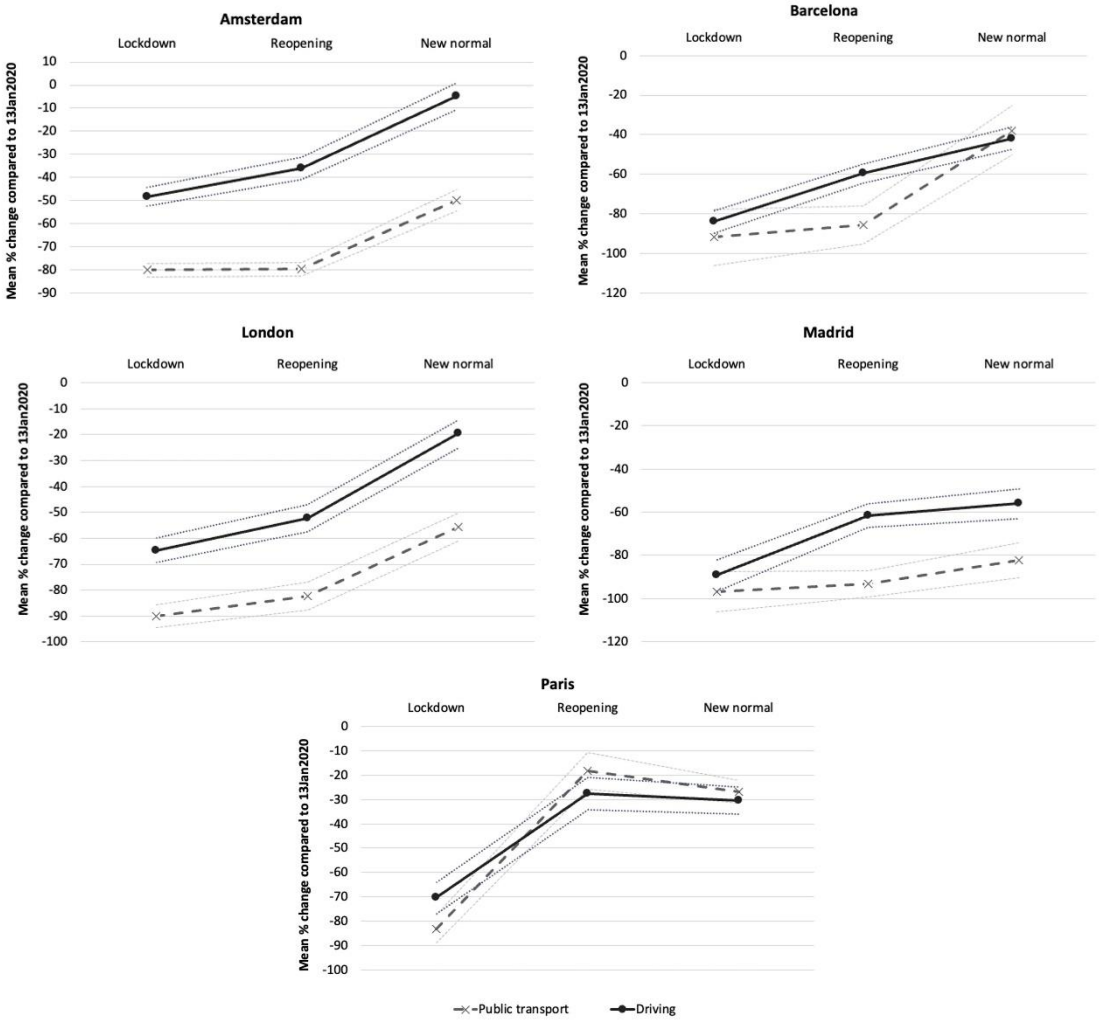
Amsterdam
Lockdown
Reopening
New normal
Mean % change compared to 13Jan2020
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Barcelona
Lockdown
Reopening
New normal
Mean % change compared to 13Jan2020
0
-20
-40
-60
-80
-100
-120
London
Lockdown
Reopening
New normal
Mean % change compared to 13Jan2020
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Madrid
Lockdown
Reopening
New normal
Mean % change compared to 13Jan2020
0
-20
-40
-60
-80
-100
-120
Paris
Lockdown
Reopening
New normal
Mean % change compared to 13Jan2020
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Public transport
Driving

Figure 2