



Staying connected

Working, and socialising, from home during the COVID-19 pandemic

November 2021



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Executive summary

COVID-19 changed the digital landscape worldwide in 2020.

With most people social distancing in their homes, digital connectivity became crucial for livelihoods, businesses, and wellbeing.

This momentous shift to online-only accelerated digital innovation and adoption by almost a decade (McKinsey Global Survey, 2020), with new ways of working, communicating and living providing the framework for the 'new normal'.

This report describes a research collaboration between NBN Co and CSIRO's Data61 to examine how this great shift of work, and social, interaction online unfolded, both through the first wave of the pandemic and the subsequent 12 months.

By identifying key online trends that occurred between March 2020 and June 2021, this analysis shines a light on how different occupations, demographics and regions adapted.

Focusing on a subset of occupations which were likely to be amenable to remote working, this analysis examines differences between areas with different numbers of professionals in these occupations.

Predictably, the strongest predictor of any given area's working from home rate is the number of office workers living there (for which we rely on the 2016 census). The other highly significant factor is the number of people who were already working from home prior to the pandemic. After accounting for these two factors, rates of remote working were surprisingly consistent.

Upload activity was used to estimate the number of people working from home, a method that more accurately reflected online interaction (e.g. videoconferencing) as opposed to passive consumption (e.g. streaming a movie).

By taking the number of residential connections in a local area (following Australian Bureau of Statistics geographical classifications) showing large (>500MB) upload volumes during working hours (9am–3pm) on Wednesdays as an indicator of remote working, this data was validated against both ABS survey data and Google mobility data.

Online socialising was measured by the number of residential connections with large (>500MB) uploads on Sundays (9am–9pm).

Figure 1 shows that in February 2020, rates of remote working were consistent across states. As COVID-19 spread and social distancing restrictions were introduced, working from home sharply increased in March.

PERCENTAGE OF HIGH UPLOAD CONNECTIONS (%)

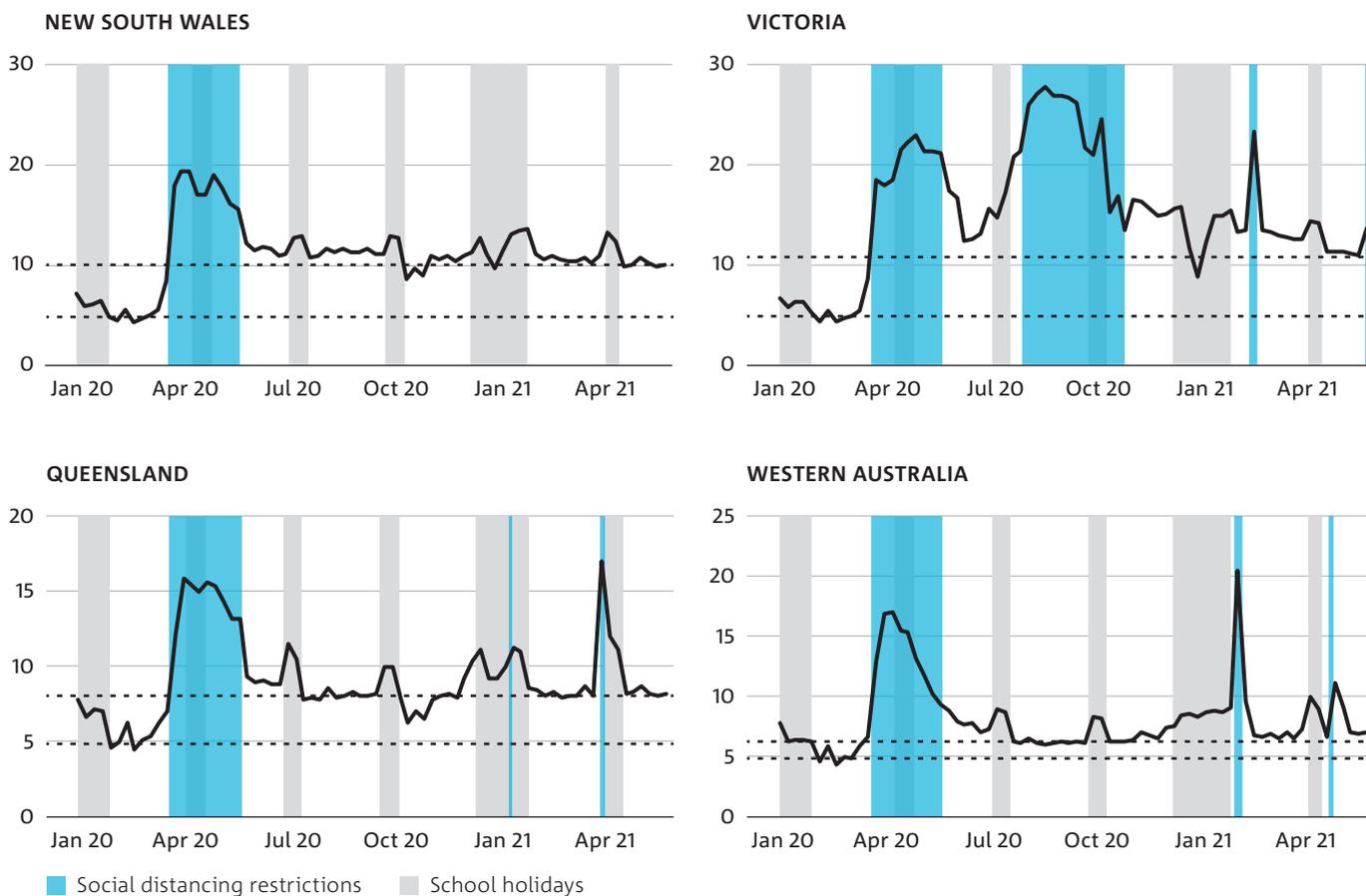


Figure 1: The percentage of NBN residential connections with high work time (Wednesdays 9am–3pm) uploads, from January 2020 through to June 2021. The lower dotted line represents a pre-COVID baseline, the upper line reflects an apparent 'new normal' level of remote working, which varies markedly between states.

As infections and restrictions declined in May, the majority of remote workers returned to their offices, resulting in a drop of online activity from private residences.

The number of people working from home remained stable for the remainder of 2020 in New South Wales, Queensland and Western Australia (along with the other states and territories, which are covered in the main report).

Victoria charted a different path due to a second wave of infections occurring from late June 2020. The rate of remote online work surged compared to that of the first wave, with a more gradual subsequent decline.

Remote working across the nation was most obvious in professions with larger numbers of managers and office workers, however, tertiary teachers (TAFEs, universities etc), medical practitioners, schoolteachers and even sports instructors also showed evidence of remote work during the early pandemic peak. Many of these groups returned to their workplace as public health restrictions eased.

In May 2021 (a period of relative COVID calm), occupations such as ICT, media, and design specialists were associated with the highest rates of remote working. Managers continued to work remotely, however less so than initially. School teachers and laboratory scientists returned to their workplaces.

Areas with more office workers aged 30–49, public transport users, and couples with children showed statistically significant, though relatively small, increases in ongoing remote work. This was highest in Victoria, followed by New South Wales and Queensland.

A wide range of other factors such as distance from the workplace, socio-economic advantage/disadvantage and house size could not explain differences in rates of remote working.

The marked differences in ongoing remote work between different states suggest that the longer people work from home, the more likely they are to persist. Ultimately, this could impact where people choose to live. A blend of working from home and in the office, otherwise known as a hybrid approach, could allow people to live further from their workplaces as they would not need to commute every day.

An increase in remote working on Sydney's fringe, particularly the Southern Highlands, between August 2020 and May 2021 is evidence of this. A similar trend can be seen on the Sunshine Coast north of Brisbane, and in other parts of coastal NSW (e.g. Byron Bay).

Online socialising, measured by upload activity on Sundays, displayed a similar pattern to that of remote working. After a sharp rise in March 2020, a plateau of elevated activity remained. Evidence of these online interactions was steady across all demographics.

Digital infrastructure such as the NBN has played a significant role in allowing Australians to physically distance during the pandemic while maintaining their livelihoods, health and wellbeing, and social interaction.

It has greatly reduced the costs of public health interventions and is also likely to have increased their effectiveness.

Many of the changes triggered by this giant remote working experiment, such as workers and their families choosing to live in different areas, will emerge gradually over coming months and years.

There is also a pressing need to examine whether those who continue to work remotely can maintain constant professional communication and a healthy level of social interaction.

If they can, many workplaces may ever be the same again.



1 Introduction

The onset of the most significant global pandemic in over a century necessitated a raft of behavioural changes (both voluntary and enforced) to slow the spread of COVID-19. People were urged, and to various extents mandated, to stay at home.

While the human toll of COVID-19 has been (and continues to be) terrible, for those fortunate to have access to digital technology the costs of staying at home can be much reduced. Unlike during previous pandemics, the physical distancing needed to reduce disease spread need not be synonymous with social distancing as technologies such as video calls and cloud computing facilitate remote interaction. While in most contexts online interaction remains an incomplete substitute for proximal (i.e. face-to-face) interaction, it has allowed a great deal of economic and social activity to be maintained during the pandemic. Countries such as Australia saw a massive shift in working habits, with large sections of the workforce switching from offices to working from home in the space of a couple of weeks from mid-March 2020.

Theoretical studies based on job descriptions suggest that 37% of US jobs can be performed fully remotely (Dingel and Neiman 2020), and this estimate is borne out by the data. In the USA 35% of the workforce moved to working from home in March 2020, though with considerable geographic and occupational variation; places with more jobs in managerial and professional occupations had higher rates of remote working (Brynjolfsson et al. 2020). Australian surveys suggest a similar percentage moved to full-time work from home in April 2020 (Beck et al. 2020), and an analysis of internet data also indicates that it is concentrated in wealthier areas where more people work in occupations that are amenable to remote work (Zachreson et al. 2020).

Opportunities for family and social interactions have also been limited. It is less clear to what extent online interactions have mitigated social isolation during the pandemic, but this is an important question given the potential impacts of loneliness on mental and physical health (Banerjee and Rai 2020).

As vaccinations reduce the risks posed by COVID-19 the need for physical distancing will reduce. However, some pandemic habits may stick. While reports of the ‘death of the office’ may be greatly exaggerated, the forced experimentation and innovation associated with mass remote working may reasonably be expected to have some lasting effects, whether through some workers switching to permanent remote work or others adopting ‘hybrid’ schedules, dividing their working week between home and office. Both these models will have significant implications beyond the workplace, such as reduced demand for peak hour commuting travel, office space and city centre cafes, and increased pressure on suburban digital infrastructure.

Remote working has clear public health benefits, reducing the numbers of people using public transport and shared workplaces, and reducing the economic costs when restrictions are imposed. In the short term remote and hybrid working is also likely to reduce many of the social and environmental costs of commuting such as congestion, pollution and road trauma. It also frees up significant amounts of time for individual workers (particularly if they are able to maintain their normal productivity) and increases self-reported wellbeing (Kazekami 2020). In the longer term it is also likely to shape where people choose to live. Previous research shows that tele-commuters tend to live further away from their offices than those who attend full-time (Mokhtarian et al. 2004; Zhu 2013), so ultimately hybrid workers may end up making fewer, longer journeys to work.

A key issue for employers and employees is how well productivity can be maintained remotely. Some tasks, such as those carried out individually and requiring deep concentration (e.g. writing that novel, or finishing that report), may be performed better remotely than in a typical modern open plan office, though with much variation depending on individual circumstances (e.g. having adequate desk space at home, and an absence of interruptions from children, pets, parcel deliveries etc). One early empirical study on IT professionals (among whom productivity is more easily measured) forced home during COVID-19 found they did 30% more hours than previously, but average output was unchanged, suggesting a decline in hourly productivity; these effects were most pronounced among those with children at home (Gibbs et al. 2021). Working from home was associated with a sharp drop in the number of interactions with colleagues despite an increase in the number of emails sent (Gibbs et al. 2021), suggesting collaboration is likely to suffer in the longer term.

A pre-COVID experimental study of Chinese call centre workers also found that working from home increased hours worked, though in this case productivity also increased; they were also less likely to quit and less likely to get promoted (Bloom et al. 2015), perhaps suggesting that their networking opportunities were limited. A related question is how much working from home will persist as the pandemic threat abates. An American survey reports that the majority of workers would like to continue at least one day per week, and many would be willing to accept a lower salary in order to do so; the study predicts that 20% of work days will be performed remotely post-COVID, compared to 5% before (Barrero et al. 2021).

Data on household internet use volumes can reveal information about the population's remote working patterns (Zachreson et al. 2020). In Australia, a large share of workers used the National Broadband Network (NBN) to work from home throughout the pandemic. NBN Co operates Australia's wholesale broadband access network, provides national, wholesale broadband access and collects data on individual household internet use volumes (uploads and downloads) across time. These data can be aggregated to assess online activity across different geographic areas. Of course, much internet activity is unrelated to people's work; streaming video, for example, accounts for a large share of download volumes.

Here we focus on uploads as they are more likely to be related to working from home, indicating online interaction such as video conferencing. These data show, at fine geographic and temporal levels, the number of households with high uploads during work time (i.e. the approximate number of households containing interactive teleworkers) across 2020 and 2021. We relate these to demographic data to demonstrate the evolution of work from home activity in different Australian regions, occupations and socioeconomic groups throughout the pandemic and explore whether the workforce is undergoing a permanent shift to greater telework.

2 Measuring remote work and social activity

2.1 Using NBN Co data to estimate remote work

A household's internet upload volumes during work time signal remote work activity, such as videoconferencing and file sharing (Zachreson et al. 2020). Download volumes, on the other hand, signal activity unrelated to remote working, such as streaming content (Zachreson et al. 2020). We therefore use household upload volumes to measure remote work. Specifically, we measure a region's remote work level in each week as the percentage of NBN connections with high upload volumes (over 500MB) during work time (9am–3pm) on the Wednesday of that week.

- We selected the 500MB threshold as it provided a clear signal of changes throughout the pandemic (based on an exploration of sample data). As a point of reference, 500MB in uploads is typically equivalent to about one hour of videoconferencing.
- We set the time window as 9am–3pm to capture remote work activity during standard work hours and avoid the potentially confounding post-school hours student usage.
- We selected Wednesdays to avoid most public holidays and pre- and post-weekend effects.
- We measured a region's remote work level as the percentage (rather than count) of high upload households to control for changes in NBN coverage over time.

This measure of remote work is closely related to the percentage of the labour force working remotely. Figure 1 compares the percentage of household connections with high work time uploads to ABS survey estimates of the percentage of the labour force working remotely in different states and months of 2020 and 2021 (Australian Bureau of Statistics 2020a). Each point indicates the values for a given state and month. The figure shows that the two quantities have a strong positive correlation. That is, changes in our measure of remote work provide a good approximation of changes in the true level of remote work. Indeed, a useful heuristic is that the percentage of the labour force working remotely is about twice the percentage of household connections with high work time uploads. Further details are provided in Appendix B.

Use of aggregated data ensures protection of Personal Information

No Personal Information was used in the collation of this analysis and report which ensures individual privacy is protected and both NBN Co and CSIRO's Privacy Act Obligations are met. Broadband data was provided at ABS Mesh Block level with totals, averages and counts aggregated at a level where no individual can be identified. The insights in this report are further aggregated to SA1 and SA2 levels, and analysed alongside aggregated data from the ABS census.

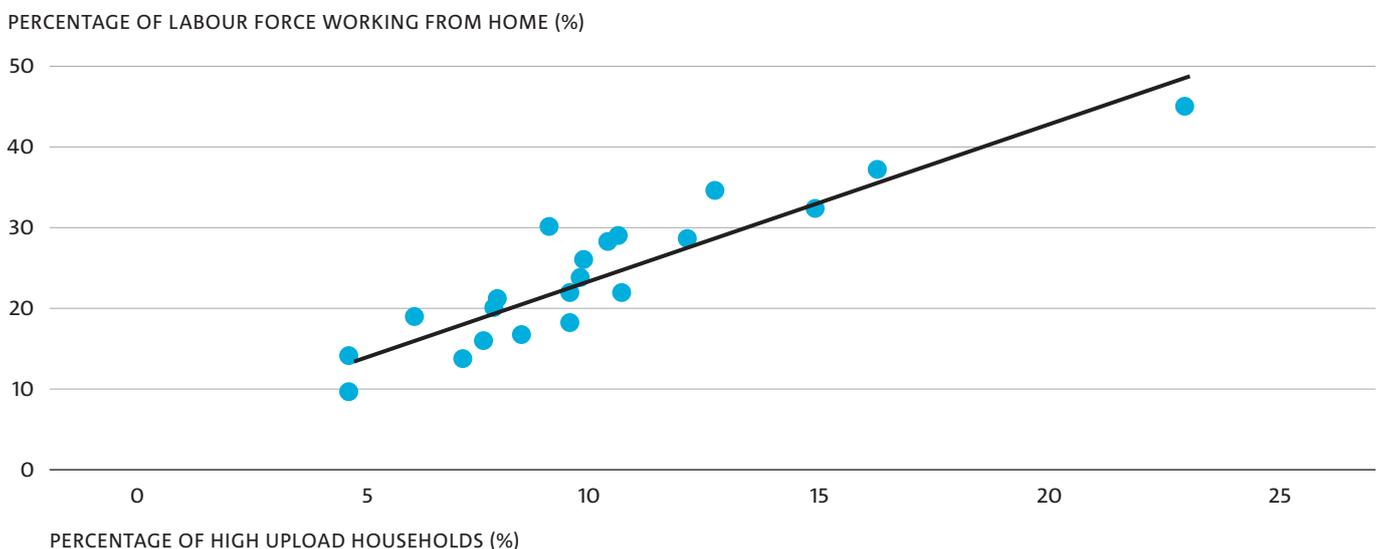


Figure 2: The percentage of NBN connections with high work time uploads and ABS estimates of the percentage of the labour force working remotely across different states and months of 2020 and 2021.

The NBN data set used in our analysis provides information on remote work activity at detailed spatial and temporal levels. It contains each mesh block's count and percentage of household NBN connections with high uploads (over 500MB) during work time (9am–3pm) on each Wednesday between January 2020 and June 2021. Mesh blocks are the ABS's smallest geographic units, with the majority containing 30–60 dwellings (ABS 2016c). In our analysis, we aggregate the NBN data to higher spatial scales, such as SA1s (containing 400 people on average) and SA2s (containing 10,000 people on average), as needed (ABS 2016c).

NBN data on household upload volumes during work hours have several advantages over other data sources in measuring remote work in Australia. First, they are high frequency (weekly in our case), enabling one to monitor telework trends throughout the pandemic. Second, they cover all regions in Australia, allowing comparisons of telework activity across different locations. Third, they are aggregated at a fine spatial level. This allows one to relate regional variation in remote work to regional variation in the population's socioeconomic characteristics to estimate the effect of various socioeconomic factors (e.g. occupation) on remote work. Finally, household upload volumes during work time are a reasonably transparent and direct measure of remote work activity. Other data sources tend to lack at least one of these features. For example, surveys on telework in Australia tend to be infrequent, aggregated at high spatial levels (e.g. state), and not cover all Australian regions (ABS 2020a; Beck et al. 2020). Meanwhile, the Google mobility measure of workplace visits uses an opaque methodology, has a higher level of spatial aggregation (local government area), and does not measure where telework is occurring (Google 2020).

A few conceptual issues in our measurement of remote work are worth highlighting. First, a region's percentage of high upload connections on a given Wednesday underestimates the region's true percentage of remote working households on that day. This is because many remote workers will not reach the 500MB threshold in the 9am–3pm window. As such, our measure does not represent the absolute level of remote work, but does indicate changes in the level of remote work over time (as shown in Figure 2). Second, our measure detects remote work activity in some occupations more than others. For example, a business professional is more likely to have videoconferences (and therefore exceed the 500MB threshold and be detected) than a clerical worker. The 500MB threshold does limit our ability to analyse remote work patterns in certain occupations; we supplemented this with a measure of the proportion of connections with a medium (50–500MB) upload volumes. Third, a region's percentage of high upload connections reflects both the number of remote workers and their level of remote work. Decreases in this percentage over time may reflect remote workers returning to the office, or remote workers doing more of their interactions (e.g. meetings) in the office as opposed to from home.

2.2 Using NBN data to estimate online socialising

A household's internet upload volumes outside of work hours signal online socialising, such as videocalls. As such, we measure a region's level of online socialising in each week as the percentage of household NBN connections with high upload volumes (over 500MB) in the 9am–9pm window on the Sunday of that week.

- We selected the 500MB threshold as it represents a reasonably high level of online interaction (equivalent to about one hour of videocalls, as noted earlier).
- We selected Sundays to avoid the standard work hours of most occupations.
- As with telework, we measured a region's online socialising level as the percentage (rather than count) of high upload households to control for changes in NBN coverage over time.

The advantages of using NBN data to measure online socialising and the associated conceptual issues are largely the same as those discussed above for telework.

2.3 Demographic data

We combine the NBN data with data from the 2016 Census to identify socioeconomic factors associated with remote work and online socialising throughout the pandemic (ABS 2016a). The Census data provide counts of individuals and families in each region that belong to certain socioeconomic groups (e.g. occupation types, age groups etc.) (ABS 2019b). Our modelling relates regional variation in telework activity and online socialising to regional variation in the population's socioeconomic characteristics to understand the effect of various socioeconomic factors on telework and socialising.

It is worth highlighting a couple of shortcomings in the Census data used in our analysis. First, the Census data were collected in 2016, making them a few years out of date for our analysis which focuses on 2020–21. The demographics of different regions will have changed since 2016 (people have moved, aged, changed jobs, retired etc.), but the broad regional variations in demographics will have remained largely the same. Second, the ABS randomly perturbs the Census data to preserve respondents' privacy (e.g. randomly adjusts the counts of workers in each occupation in each region) (ABS 2019b). These adjustments are normally small, but can have a large effect on small totals, such as detailed occupational counts at the mesh block level. In our analysis we aggregate the Census data at moderate spatial (SA1 and SA2) and socio-economic levels to minimise the effect of this random perturbation.



3 Remote work in the pandemic

3.1 The shift to working from home

The second half of March 2020 saw an unprecedented shift in employment in Australia. Millions of office workers switched to working from home often with minimal preparation. While this was challenging, it enabled large numbers of people to maintain their income while also being largely protected from the pandemic. Those fortunate enough to be able to work remotely were certainly in a privileged position, as many others lost work entirely while ‘essential workers’ who could not work remotely faced the greatest risk of COVID-19 infection.

Figure 3 shows the percentage of NBN connections with high uploads during work hours (9am–3pm) on Wednesdays between January 2020 and June 2021, which serves as our proxy for remote working, across each Australian state and territory. The periods shaded in blue had strict social distancing restrictions (‘lockdowns’). The periods shaded in grey were school holidays. The remaining periods can be considered reasonably normal work times. The dashed lines show remote work levels pre-pandemic (February 2021) and the ‘new normal’ in June 2021 (which was a relatively stable period with few cases and restrictions). School holiday periods (shaded grey) are associated with increased upload activity; it is unclear from the data whether this is due to school students connecting online or parents being more likely to work from home during school holidays.

Figure 3 highlights the speed and extent of the shift to home working in March 2020. From a pre-pandemic baseline of approximately 5%, the proportion of households in which someone appeared to be working from home (as indicated by high upload volumes during working hours) jumped to 15–20%. Remote working was highest in NSW, Victoria and the ACT, reflecting higher proportions of the occupations which are most amenable to it (see below).

It is also notable how rapidly remote work declined as restrictions were eased through May and June 2020, settling at a relatively consistent level from August 2020 onwards (indicated by the upper dashed line). Victoria followed a different trajectory due to a major second wave of infections from mid-2020 which led to tighter restrictions (which required permits for workplace attendance) and an even higher level of observed remote working.

Figure 3 also shows how ‘snap lockdowns’ (indicated by the thin blue lines) see remote working spike back up to levels around those observed early in the pandemic, before typically reverting rapidly back to the ‘new normal’ afterwards. While the baseline level of remote working was relatively consistent across jurisdictions, there is considerable variation in the ‘new normal’. Part of this reflects occupational and demographic differences, which are analysed in detail below. However, it should also be noted that the path of the pandemic differed greatly between states. Victoria is clearly an outlier in 2020, but NSW also had ongoing cases from June to November 2020 and a larger outbreak in late December. This ongoing COVID risk is likely to have increased people’s propensity to continue working from home. In contrast Western Australia saw no community transmission in the second half of 2020 and returned much closer to its pre-COVID baseline.

PERCENTAGE OF HIGH UPLOAD CONNECTIONS (%)

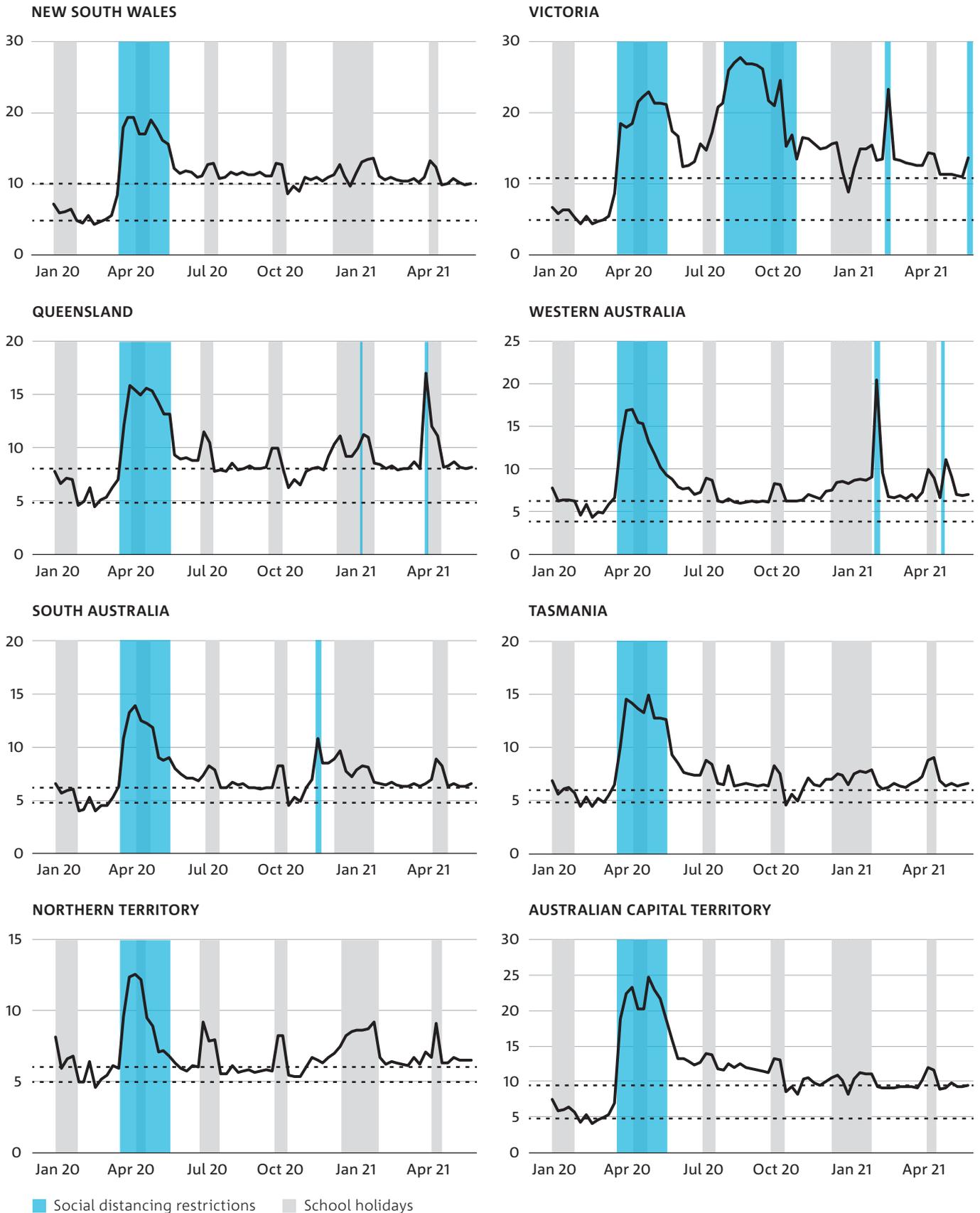


Figure 3: The percentage of NBN residential connections with high work time uploads in each state and territory.

Figure 4 relates community COVID cases in each jurisdiction up until the end of May 2021 to differences in working from home in May 2021 beyond what can be explained by occupational and demographic differences (see Appendix E) (COVID Live 2021). The pattern suggests that the level of COVID a state has experienced may account for some of this additional variation on ongoing working from home. This may be because more COVID cases encourage workers, and their employers, to do more working from home; people may also invest more, for example upgrading their home office furniture, and employers invest in better remote systems.

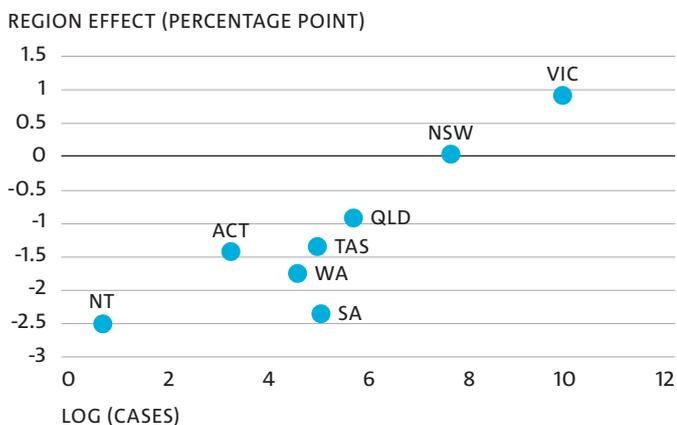


Figure 4: Variation between states and territories in the persistence of working from home, once occupational and demographic differences had been accounted for, compared to community transmission of COVID (up to 31 May 2021). NSW is the reference level; Victoria showed consistently higher levels of working from home than NSW, while the other jurisdictions were lower.

This could be why a state such as Western Australia, which had very little COVID transmission, also has lower rates of working from home in May 2021 than many other states. Unfortunately Australia has insufficient states and territories for us to test this association more rigorously.

Much of the telework adoption throughout the pandemic occurred in the capital cities, which are home to most of Australia’s workers (69%) and potential teleworkers (77%) (ABS 2016 j). Here, we have defined a potential teleworker as anyone in an occupation highly conducive to telework (see Appendix D for the full definition). Sydney, Melbourne, and Brisbane alone account for 51% of the labour force and 58% of potential teleworkers (Figure 5 provides the full breakdown by region) (ABS 2016j).

We estimate that in May 2021 around 22% of Australia’s labour force worked from home on any given workday, excluding the snap lockdowns in Victoria and Western Australia (see Appendix B.2 for the methodology behind this estimate). This represents a significant increase on pre-pandemic working from home rates of 5–6% (Appendix C). We also estimate that working from home rates varied significantly by region, with areas that experienced sustained outbreaks such as Melbourne (28%) and Sydney (27%) showing higher rates than less-affected areas such as Perth (18%).

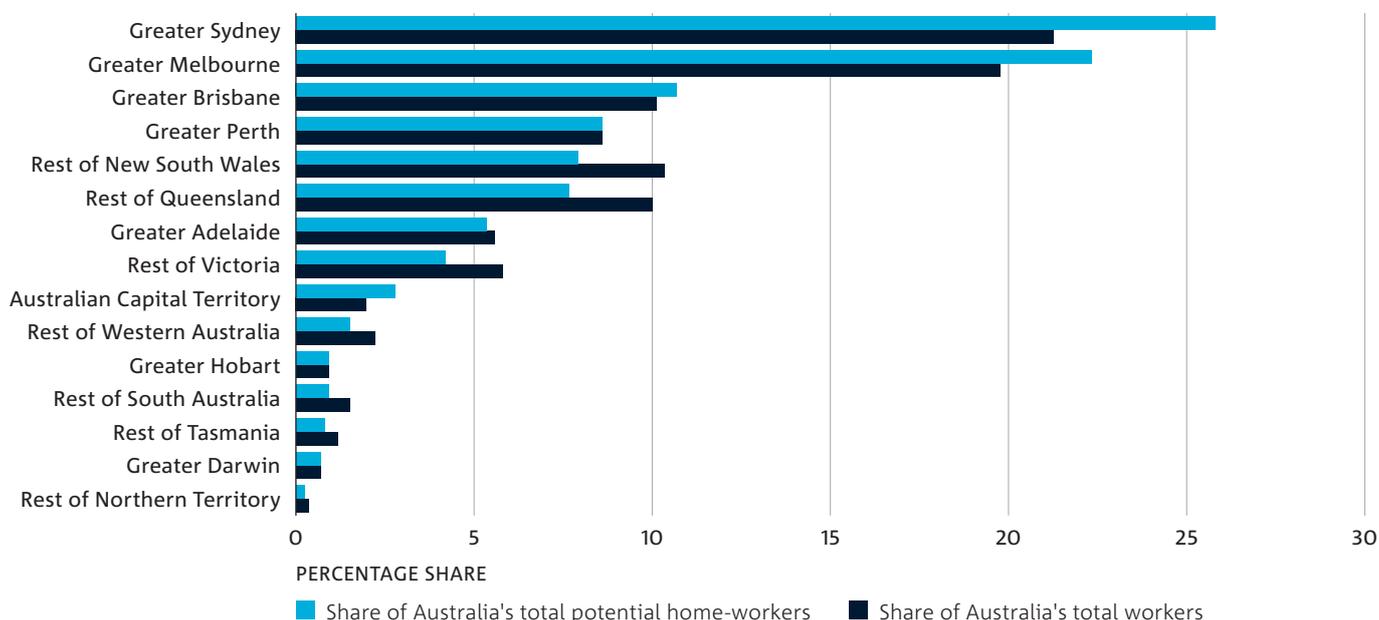


Figure 5: Each region’s share of Australia’s total workers and potential teleworkers.

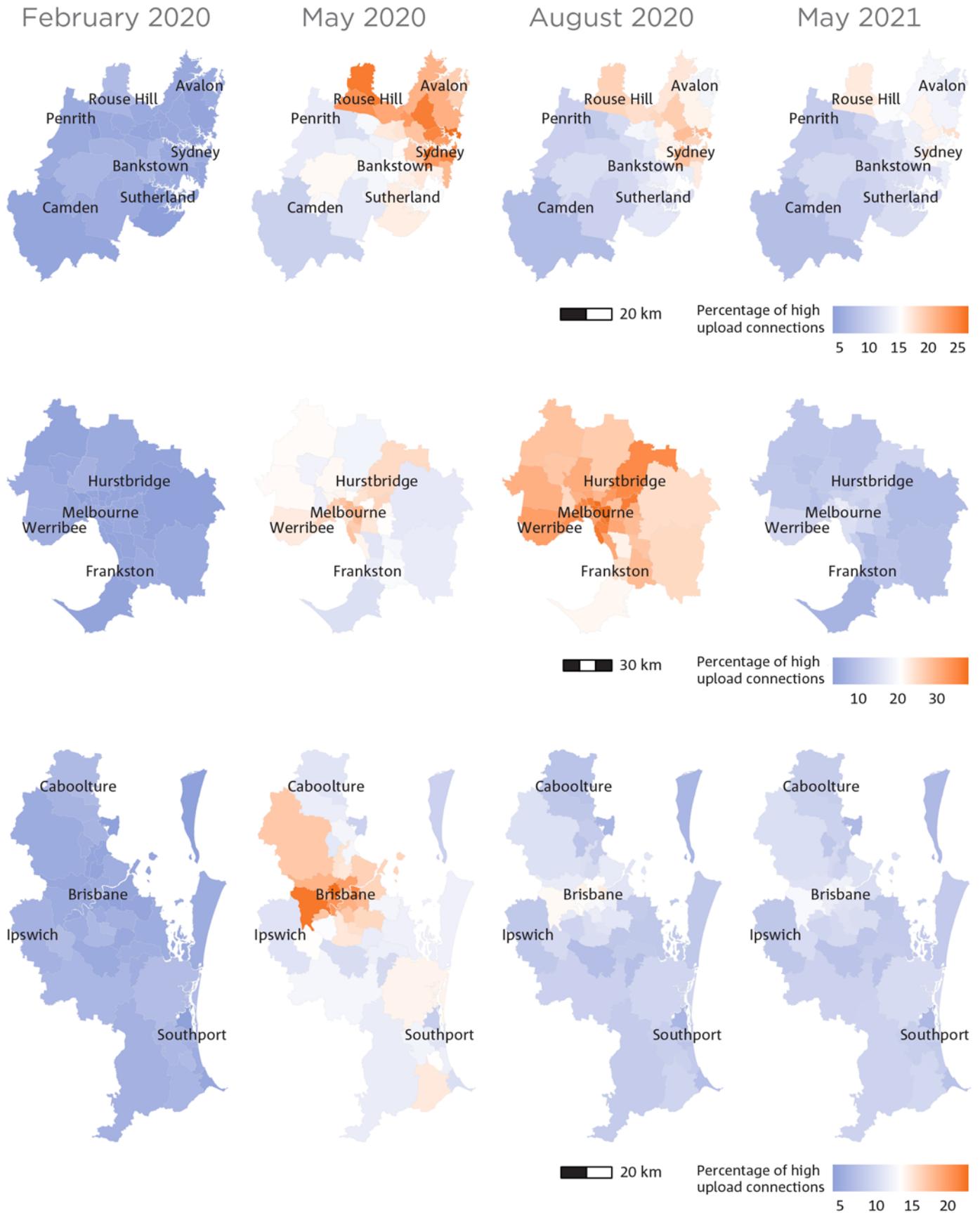


Figure 6: The percentage of high upload connections during work hours in each SA3 in Sydney, Melbourne and Brisbane at key points throughout the pandemic.

In each of the major cities, the spatial distribution of telework throughout the pandemic followed a similar trajectory, except for during Melbourne's prolonged second lockdown. Figure 6 shows the percentage of high upload connections in the different districts ('SA3s' – an urban hub containing 30,000–130,000 people (ABS 2016c)) within the largest cities at key points throughout the pandemic. The panel for February 2020 shows that telework levels were uniformly low before the onset of the pandemic in March. The panel for May 2020 shows that at the peak of the pandemic telework levels increased across each city, with the largest increases concentrated in suburbs around the CBD. The panel for August 2020 shows a significant dampening of telework levels from May 2020, except for in Melbourne where telework surged to new heights under the second lockdown. The panel for May 2021 shows that telework levels remain above their pre-pandemic levels, particularly around the CBDs.

3.2 Remote working by occupation

We developed a series of regression models to test which socio-economic and demographic factors were most closely associated with remote work. These models can include several different factors and determine which are statistically significant in terms of accounting for variation in observed levels of teleworking. When correctly specified, the models allow one to infer the effect of each variable on the level of remote work while holding all other variables constant (Angrist and Pischke 2008).

The NBN data and Census demographic data used in our analysis are aggregated at a fine spatial level. This fine level of aggregation provides a large sample of spatial units and creates substantial variation across the different spatial units in both remote work activity and demographics. This allows the specification of complex models to estimate, for example, the level of remote work in different detailed occupational groups (such as engineers and lawyers).

The full details of these models are described in the appendices; here we will describe the key findings. Unless stated otherwise, the effects we describe are all 'statistically significant', meaning our models suggest we can reasonably certain that the effect we observe is real and has not occurred by random chance.

Clearly some occupations are far more amenable to remote working than others. To explore variation among different occupations further we focused on the occupations that could conceivably be worked remotely (ruling out occupations such as labourers, trades workers etc.). This left us with 41 out of 134 occupational categories (at the ANZSCO 3-digit level for those following at home), which are listed in Figure 7 (ABS 2006; ABS 2019a). We then modelled local (SA1 level) variation in telework levels against the number of people working in different occupations within that local area, while controlling for other potentially relevant variables (e.g. percentage of population in other occupations, student population, mean household size, state, city vs non-city indicator etc.). Figure 7 shows the relative levels of remote work observed for each of these occupations while working from home was at its peak early in the pandemic (April and May 2020). Overall, 33 out of our 41 'teleworkable' occupations showed significant evidence of teleworking via the NBN over this time; these occupations account for about 35% of the Australian workforce (ABS 2016j).

Remote working was most obvious in areas with a larger number of managers and professionals (Figure 7). However, it extended beyond typical office occupations, with tertiary teachers (TAFEs, universities etc.), medical practitioners, schoolteachers and sports instructors all showing some evidence of teleworking during the early pandemic peak. A number of clerical occupations which in theory are highly 'teleworkable' could not be seen in this data. This may be because they make less use of high upload interactive tools such as videoconferencing and so cannot be seen in our data. Repeating the analysis using our 'medium' upload category (50-500MB) found evidence of remote activity among most of the clerical and business occupations which were not observed when looking at high (>500MB) upload activity.

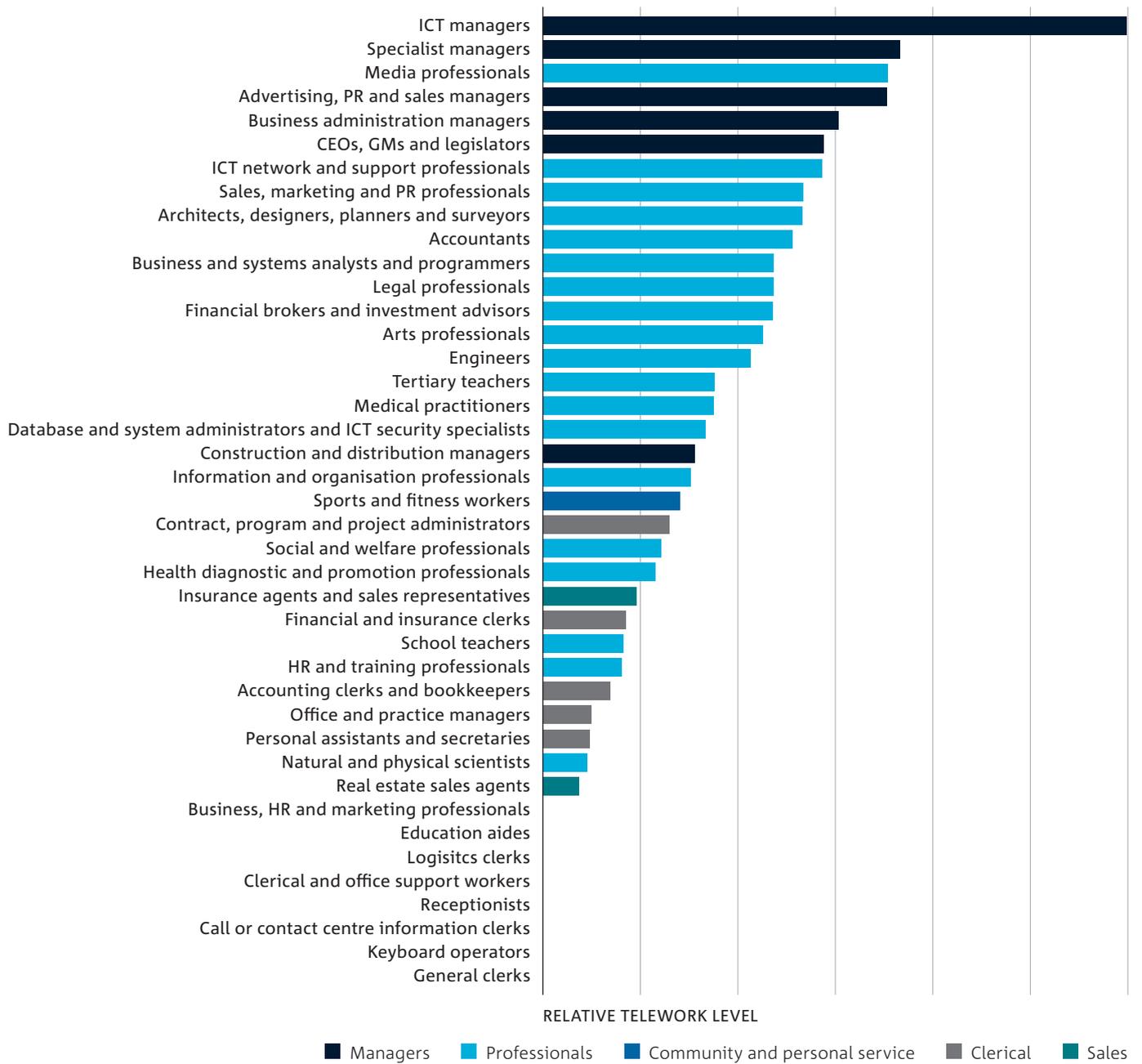


Figure 7: Prevalence of high (>500MB) upload teleworking associated with different occupations early in the pandemic.

3.3 Persistence of remote working

The above results provide an interesting record of which occupations were most likely to switch to working from home when required. This documents the key role of the NBN and other digital infrastructure in facilitating a remarkable relocation in economic activity, which allowed many people to both keep working and avoid being exposed to COVID risk. However, a more important question is to what extent remote working will persist as the COVID threat (hopefully) diminishes. For many, working from home was a forced experiment, and over the weeks and months both individuals and organisations have been innovating to make it more effective. This has included everything from enhanced virtual private networks (VPNs) to maintain cybersecurity remotely to ergonomic furniture to make remote work safer. This process is likely to improve the productivity of remote work into the future, even as it becomes less necessary.

While in-person interaction is likely to remain the preferred model for many, the costs of not being physically present are clearly reduced through newly adopted technologies such as videoconferencing. As the same time there may have been a shift in expectations, with remote work perhaps now considered more routine and acceptable in many organisations than it was prior to COVID. This will have profound consequences on urban economies, including changed commuting patterns, less demand for city office space, greater demand for suburban dwelling space, shifts in energy consumption, digital infrastructure requirements and more.

We examined this question by looking at remote working in May 2021 to determine which types of workers were more likely to be working from home 12 months on from the initial peak. Each major city was modelled separately due to their differing characteristics and pandemic experiences. We modelled the percentage of connections showing high upload volumes at the SA2 level – a statistical area which typically align to suburbs (ABS 2016c). Our regression models closely fitted the data for each city, suggesting the findings are likely to be robust.

Two factors proved particularly important in explaining variation in rates of remote working. Firstly, areas where more people appeared to be working from home pre-COVID had higher rates of remote working during the pandemic. This suggests that the pandemic has accelerated a pre-existing trend in remote working, which has been growing steadily, albeit from a low base, facilitated by improved communications technology (Appendix C). The other key factor was the percentage of ‘office professionals’ within the local area – a group that includes managers and a range of business, legal, ICT and engineering professionals (see Appendix D for full list). These occupations are well suited to remote working as they involve working with information and people rather than physical equipment. They are also likely to be highly interactive and so leave a clear trace in internet upload data volumes.

A number of other factors had a statistically significant, though more modest, impact. There was an age effect, with 30–49-year-old office professionals associated with more persistent working from home than their younger or older peers. A higher proportion of households containing couples with children also correlated with higher remote work levels. The final factor was public transport use, which was positively associated with remote working. It is also worth noting some of the many factors which proved non-significant in the models. For example, commuting distance, income, wealth and housing quality (e.g. spare bedrooms), were not associated with telework persistence once key factors such as occupation and age were accounted for. This means that while in practice areas with higher incomes may see more teleworking, the models indicate it is associated with the occupational mix of those areas (i.e. more managers and professionals) rather than incomes per se – areas with identical occupational mixes but different incomes, or commuting distances, would not be predicted to show consistent differences in remote working.

These patterns were similar across the five largest cities (Sydney, Melbourne, Brisbane, Perth and Adelaide), though the public transport effect was not significant in Adelaide and age was less important in Brisbane, Perth and Adelaide (Table 1; see Appendix E for model outputs).

Table 1: Regression model results for variables associated with persistent teleworking. Bright blue indicates statistically significant and large effect; light blue indicates statistically significant but small effect; grey indicates no statistically significant effect.

REGRESSION WEIGHTS: SOCIO-ECONOMIC FACTORS AND THE PERSISTENCE OF REMOTE WORK					
SUBURB CHARACTERISTIC	SYD	MEL	BRIS	PERTH	ADEL
Proportion of connections with high work time uploads in Feb 2020	Bright blue				
Proportion of population working as office professionals	Bright blue				
Proportion of office professionals commuting via public transport	Light blue				Grey
Mean commute distance of office professionals	Grey				
Proportion of office professionals aged 30–49	Light blue		Grey		
Couples with children as a proportion of all households	Light blue				
Index of Economic Resources percentile	Grey				
Proportion of households with a spare bedroom	Grey				

3.4 Telework persistence by occupation

To examine occupational variation in telework persistence more closely we used a more detailed occupational classification, focusing on the same subset of ‘teleworkable’ occupations as in Section 3.2. We fitted regression models to estimate each occupation’s telework levels in May 2021 and May 2020, and then compared the levels to measure the extent to which remote working had persisted relative to its early pandemic peak (please see Appendix E for a more technical, but probably equally opaque, explanation). Figure 8 shows that teleworking appears particularly persistent in a number of occupations such as ICT, media, information and architectural professionals.

The larger professional occupations such as accountants, lawyers and engineers have maintained moderate levels of telework while schoolteachers and real-estate agents are (as expected) no longer teleworking. It is also interesting to note the comparison with Figure 7; managerial occupations showed some of the highest teleworking levels early in the pandemic, but as restrictions have eased they have returned to the office to a greater extent than most professional occupations, perhaps reflecting the greater importance of in-person interactions to managers.

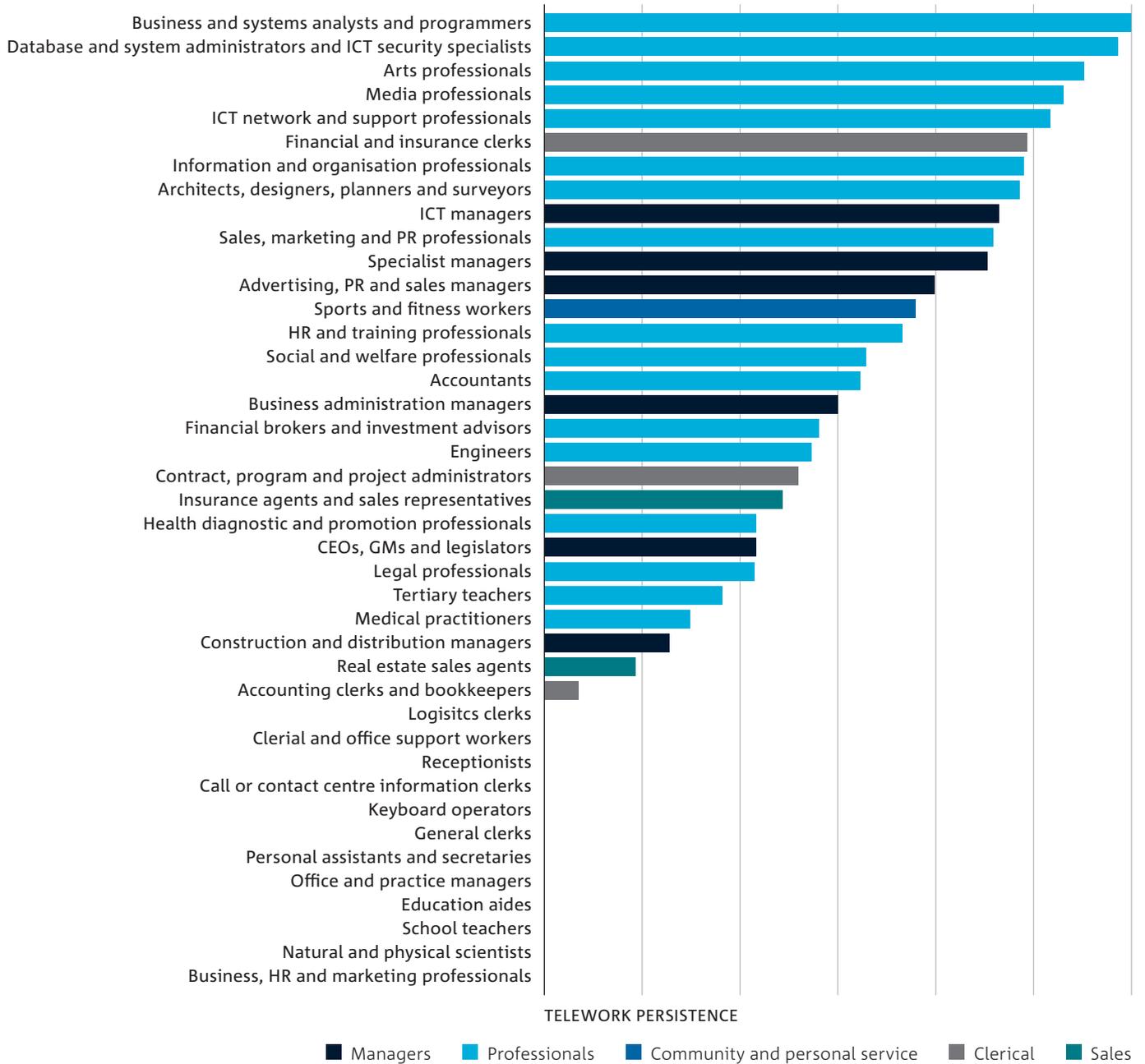


Figure 8: Telework persistence by detailed occupation.

3.5 Where is telework persisting within cities?

Figure 9 shows that while inner and outer suburbs (see Appendix D for definition) of our major cities have differing levels of remote work the trends tend to be similar across each city. Workers in outer suburbs appear to have returned to their workplaces more rapidly as restriction ease, which is likely to reflect their different occupational mix. Overall levels of telework have remained relatively constant over recent months across both inner and outer areas.

The detailed spatial distribution of persistent telework in each city largely reflects where office professionals currently live. This is shown in Figure 10 below – the left panel shows the percentage of office professionals in each area, and the right panel shows the percentage of high upload NBN connections on Wednesdays in May 2021 (the plot for Melbourne excludes the week where it had a short lockdown) (ABS 2016k). There is a high correlation between these variables, but also a few clear exceptions: the regions around Rouse Hill in Sydney, Werribee in Melbourne, and north of Southport in Queensland (Coomera and Ormeau) have high levels of ongoing telework relative to their proportions of professionals.

The fact that most office professionals live close to the CBD limits some of the gains from telework in terms of reduced commuting times and environmental benefits. Proximity to the CBD would have been a factor in many office professionals’ decisions about where to live. Now that many of them are working remotely (at least some of the time), living near the CBD has become less important, making it likely that some office professionals will relocate to regions further from the CBD over time.

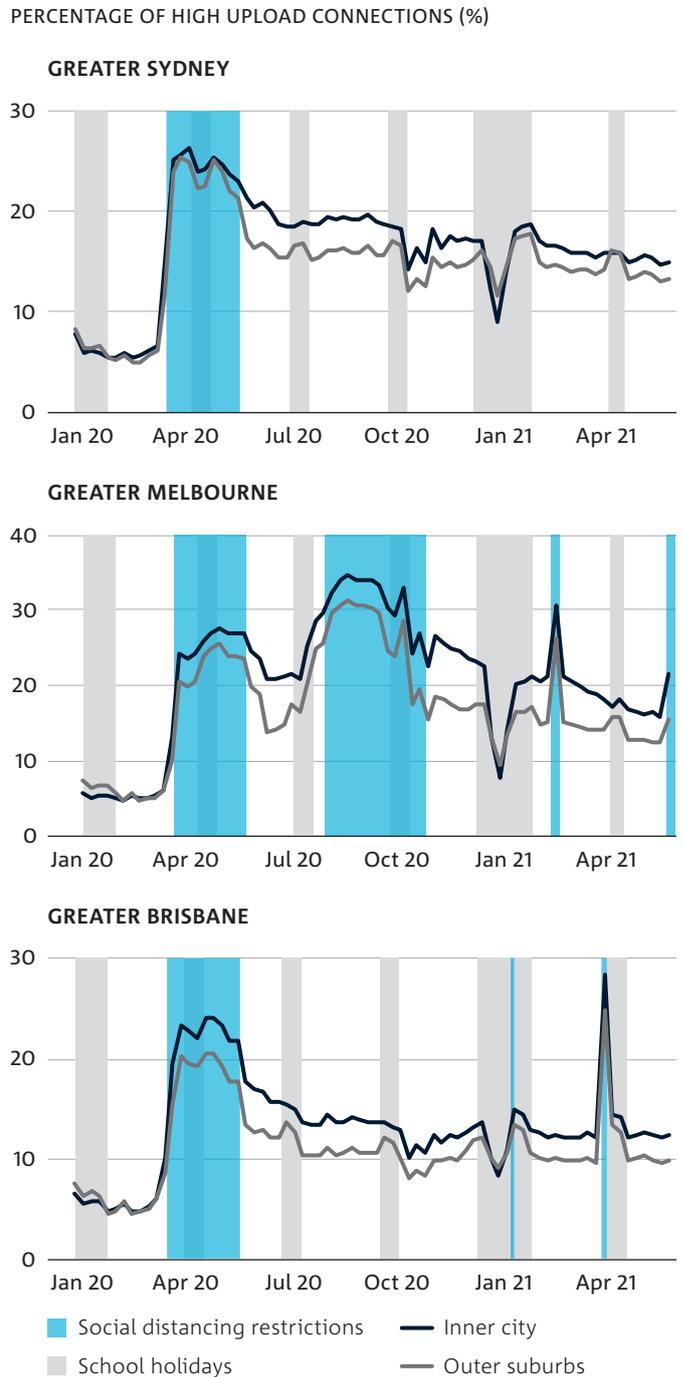


Figure 9: Percentage of household NBN connections with high uploads during work time in the inner and outer suburbs of Sydney, Melbourne, and Brisbane.

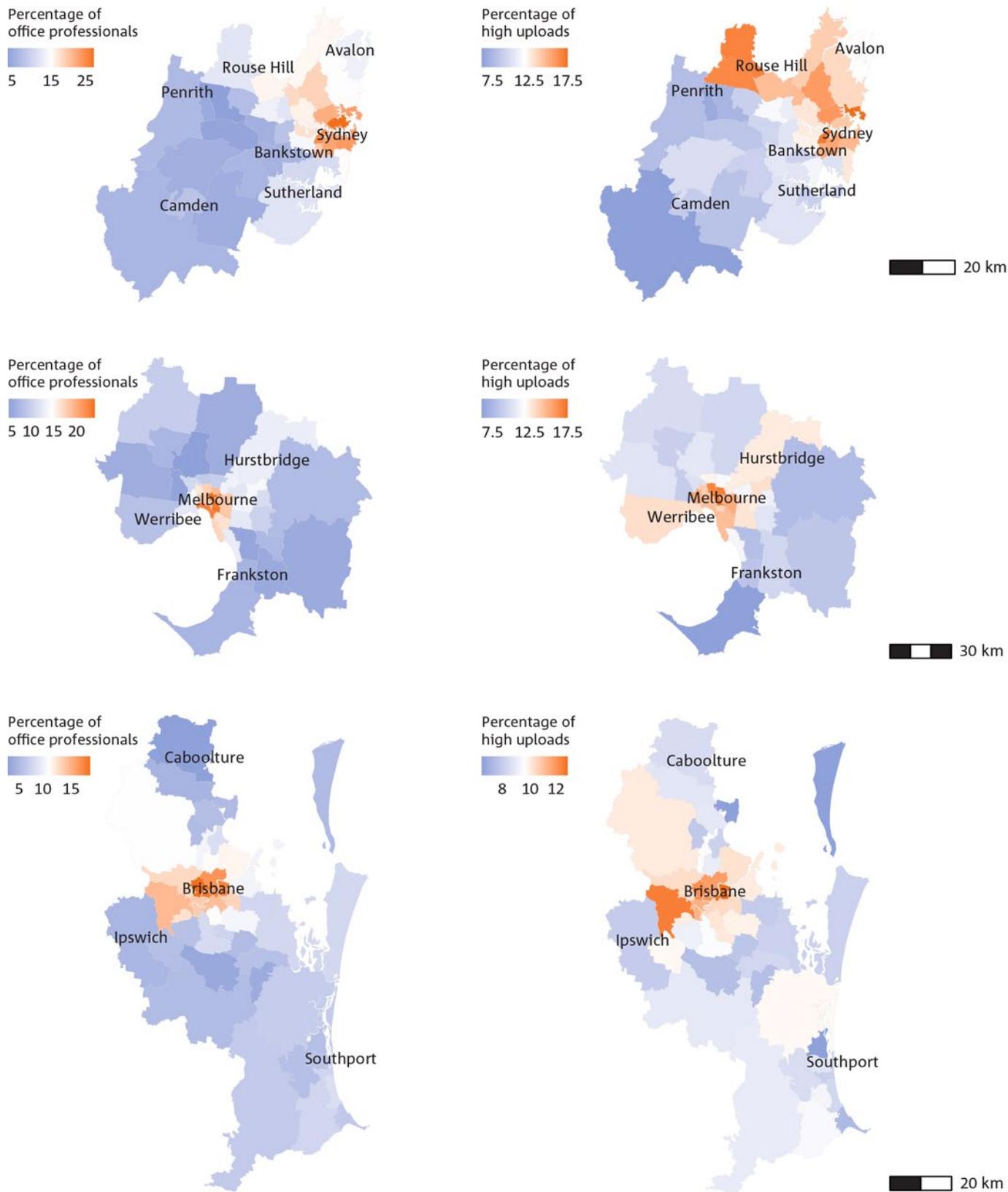


Figure 10: Office professionals as a percentage of the population (left column) and the percentage of household NBN connections with high uploads during work time (right column) for each SA3 in Sydney, Melbourne, and Brisbane.

3.6 Regional remote working

While for many workers the pandemic has meant lost jobs or reduced hours and ongoing risk of COVID exposure, for those fortunate enough to be able to work remotely it has actually increased their options. While offices have reopened as restrictions ease, many workers have continued to work from home. Many employers are supporting 'hybrid' models, encouraging workers to attend the office for two or three days a week while a minority of workers are likely to remain remote indefinitely. This reduced need to physically attend workplaces reduces the costs of living further away and so may be expected to result in some office workers relocating to more distant areas which may offer increased amenity and/or lower property prices.

A region experiencing an influx of office professionals will have a greater percentage of high upload connections during work time in May 2021 than that expected based on its demographics relevant to NBN use. However, this does not necessarily translate to an increase in the total number of high upload connections as such regions may be subject to two opposing forces: a slight trend towards returning to the office for existing residents, offset by an inflow of new remote workers.

If the former exceeds the latter, the count of high upload connections may decrease despite the inflow of new residents. We analysed the percentage of high upload connections in May 2021 compared to February 2020 (as a pre-COVID baseline) and August 2020 (as the 'new normal' baseline) to identify regions with greater than weekday upload activity, which would be consistent with remote workers relocating between August 2020 and May 2021 (see Appendix E for the full model).

Figure 11 illustrates the results for NSW, with indications of increased remote working in regions around the fringes of Sydney along with some coastal regions; the strongest growth was in the Southern Highlands south of Sydney (around Moss Vale). In Queensland there is evidence of strong growth in remote working on the Sunshine Coast (north of Brisbane) as well as the Gold Coast hinterland (Figure 12).

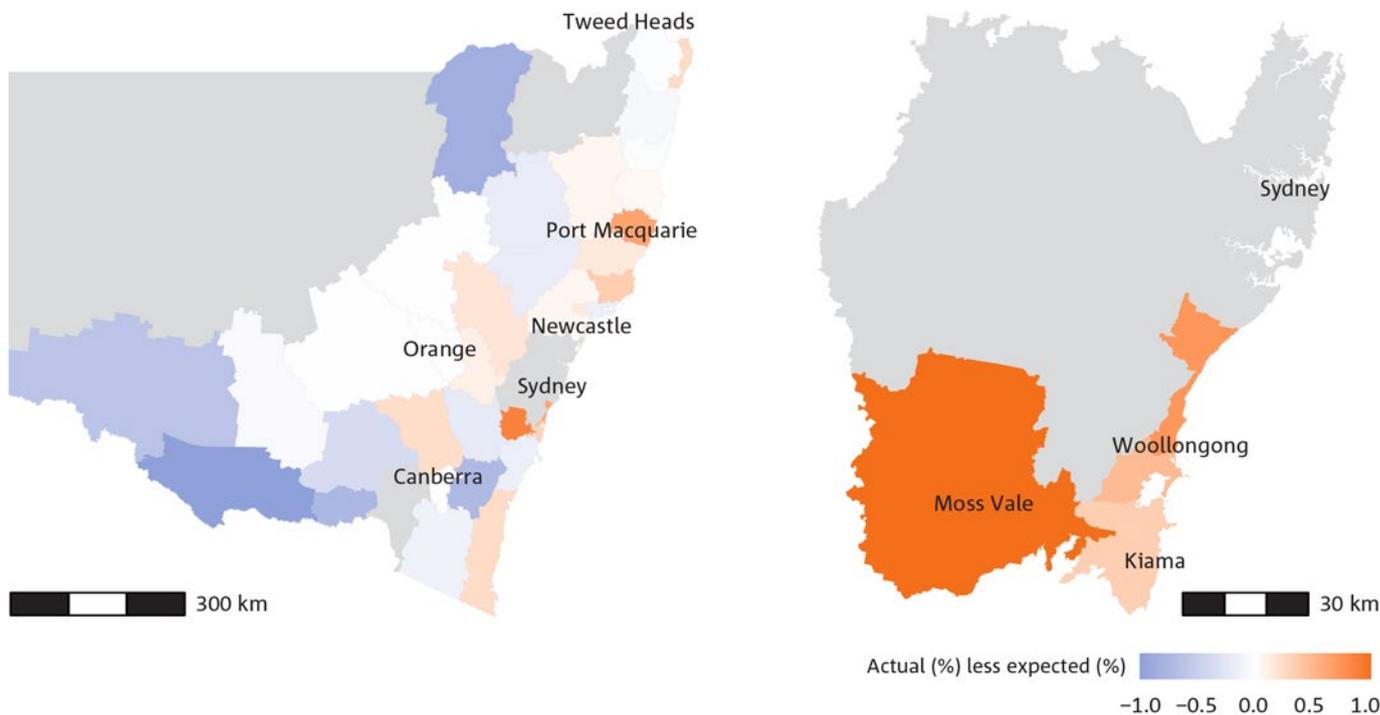


Figure 11: NSW regions (SA3s), showing deviation from 'expected' levels of remote working in May 2021; red shading indicates higher than expected remote working, consistent with an increase in the regional population of remote workers (greater Sydney and regions with limited data are shaded grey).

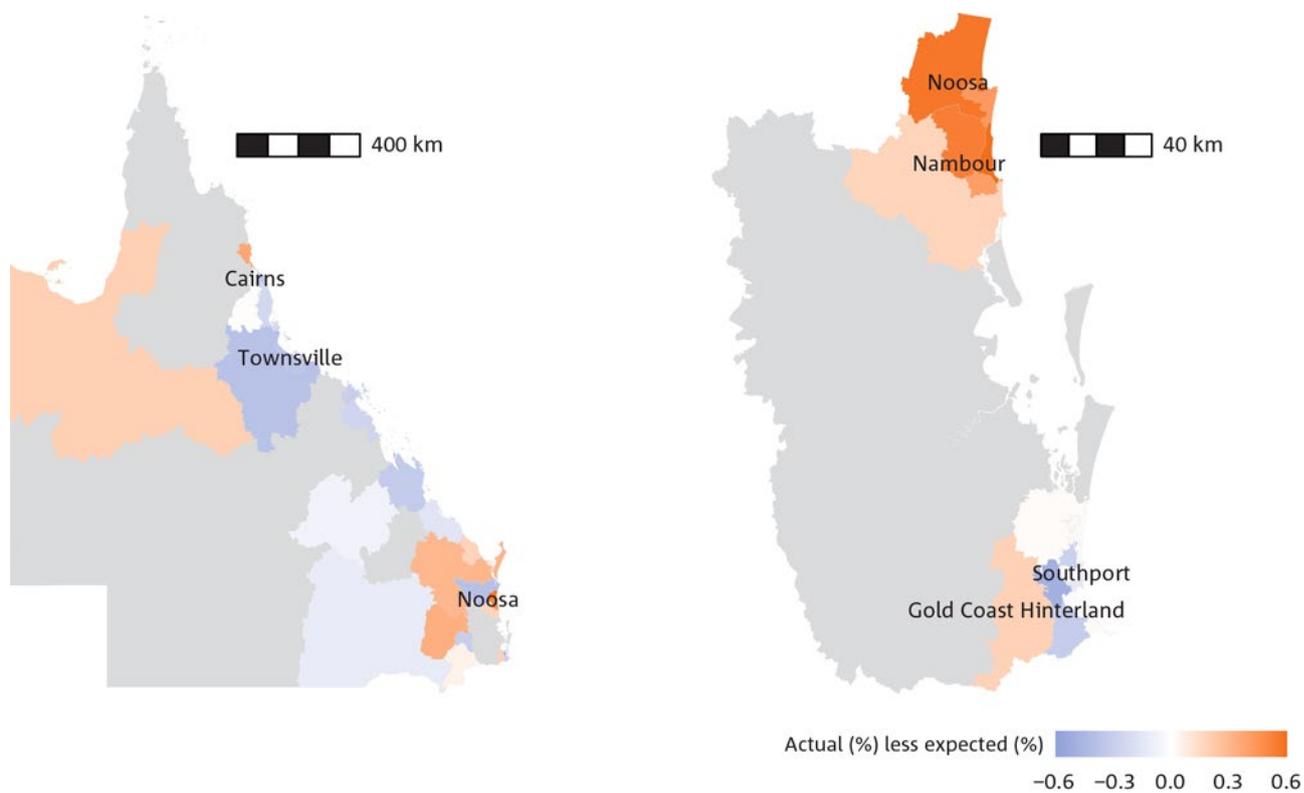


Figure 12: Queensland regions (SA3s), showing deviation from 'expected' levels of remote working in May 2021; red shading indicates higher than expected remote working, consistent with an increase in the regional population of remote workers (greater Brisbane and regions with limited data are shaded grey).



4 Socialising in the pandemic

4.1 The shift to online socialising

We applied a similar methodology to estimate the number of households showing evidence on online socialising. We focused on Sundays, as the day when Australians are least likely to be doing office work, and counted the number of connections in each mesh block with uploads above 500MB between 9am and 9pm. As for remote working, uploads are indicative of online interaction, as distinct from downloads which are more likely to involve passive consumption.

The data show clearly that people rapidly increased their online socialising at the onset of the pandemic, and associated movement restrictions, in March 2020. Figure 13 shows the percentage of household NBN connections with high uploads on each Sunday between January 2020 and June 2021 by state and territory. All regions show large spikes during the lockdown periods, indicating a broadscale shift to online activity. In many states the decline started well before the official end of the first lockdown, but this is likely to reflect gradually easing restrictions, for example allowing some home visitors, which would have reduced some of the need for online interactions.

As with remote working, much of this increase was maintained in the ‘new normal’ from June 2020 onwards, and responds rapidly to new lockdowns. This suggests that people are indeed using the NBN to stay connected during the pandemic, and that at least some of this changed behaviour is likely to persist. However, unlike remote work, the need for online interactions has been more ongoing, as interstate and international travel restrictions keep many of us apart from family and friends. These data are rather more noisy (i.e. fluctuating from week to week) than the weekday data, suggesting that online social interactions are more responsive to things such as weather – the data tend to spike upwards on wet weekends and down on long weekends (as some people are away).

While many households were clearly connecting online during the pandemic, there may still be pockets of social isolation. Examining the data at a fine-grained spatial scale (SA1) showed that virtually every single SA1 across the country had an increase in online activity on Sundays during the pandemic compared to February 2020. The increase in activity was greatest in the capital cities but occurred pretty much everywhere (Figure 14), suggesting technology helped many people stay connected even when physically distanced.

PERCENTAGE OF HIGH UPLOAD CONNECTIONS (%)

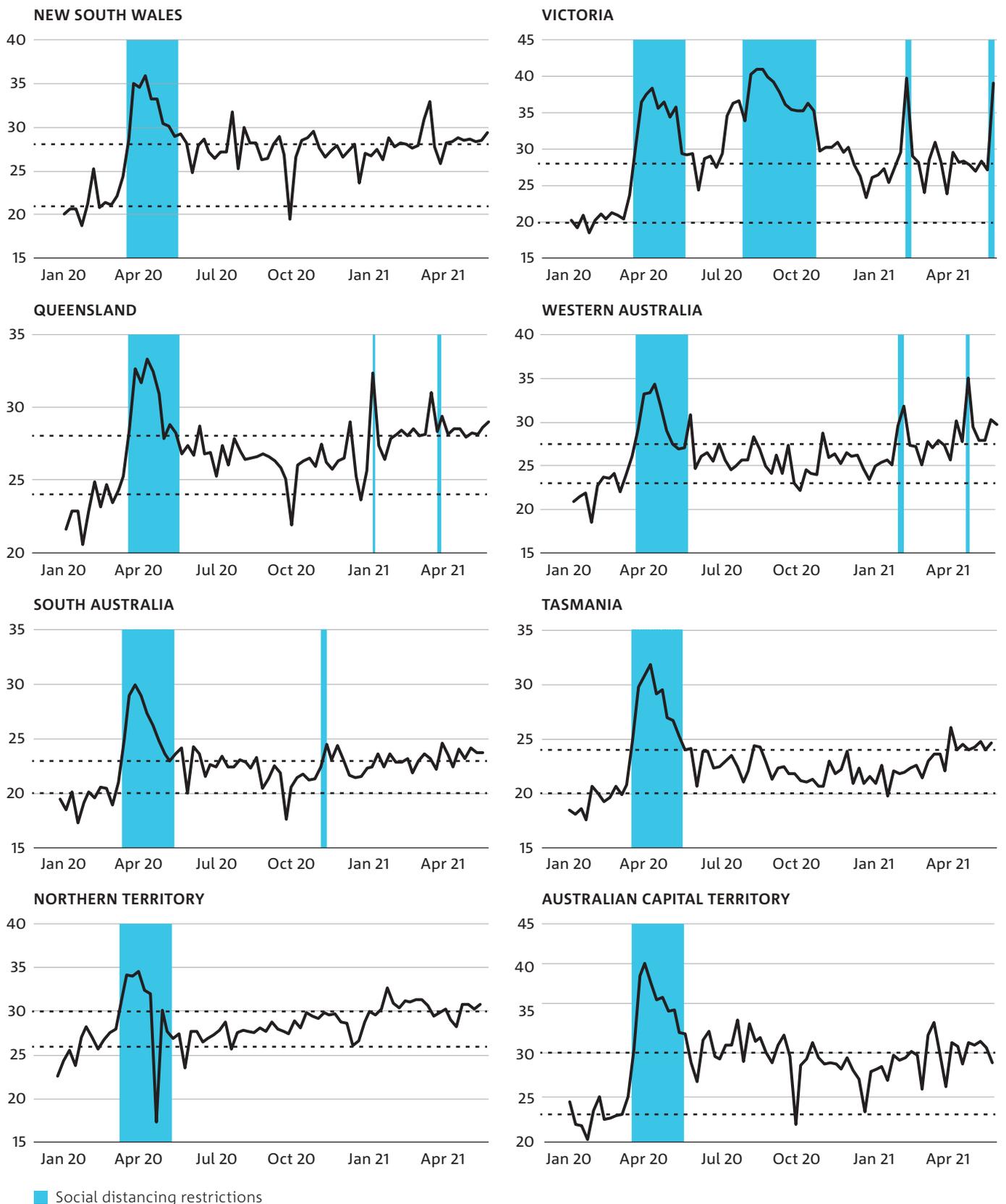


Figure 13: The percentage of household NBN connections with high uploads (>500MB) between 9am and 9pm on Sundays in each state and territory.

PERCENTAGE OF HIGH UPLOAD CONNECTIONS PEAK-PANDEMIC (%)

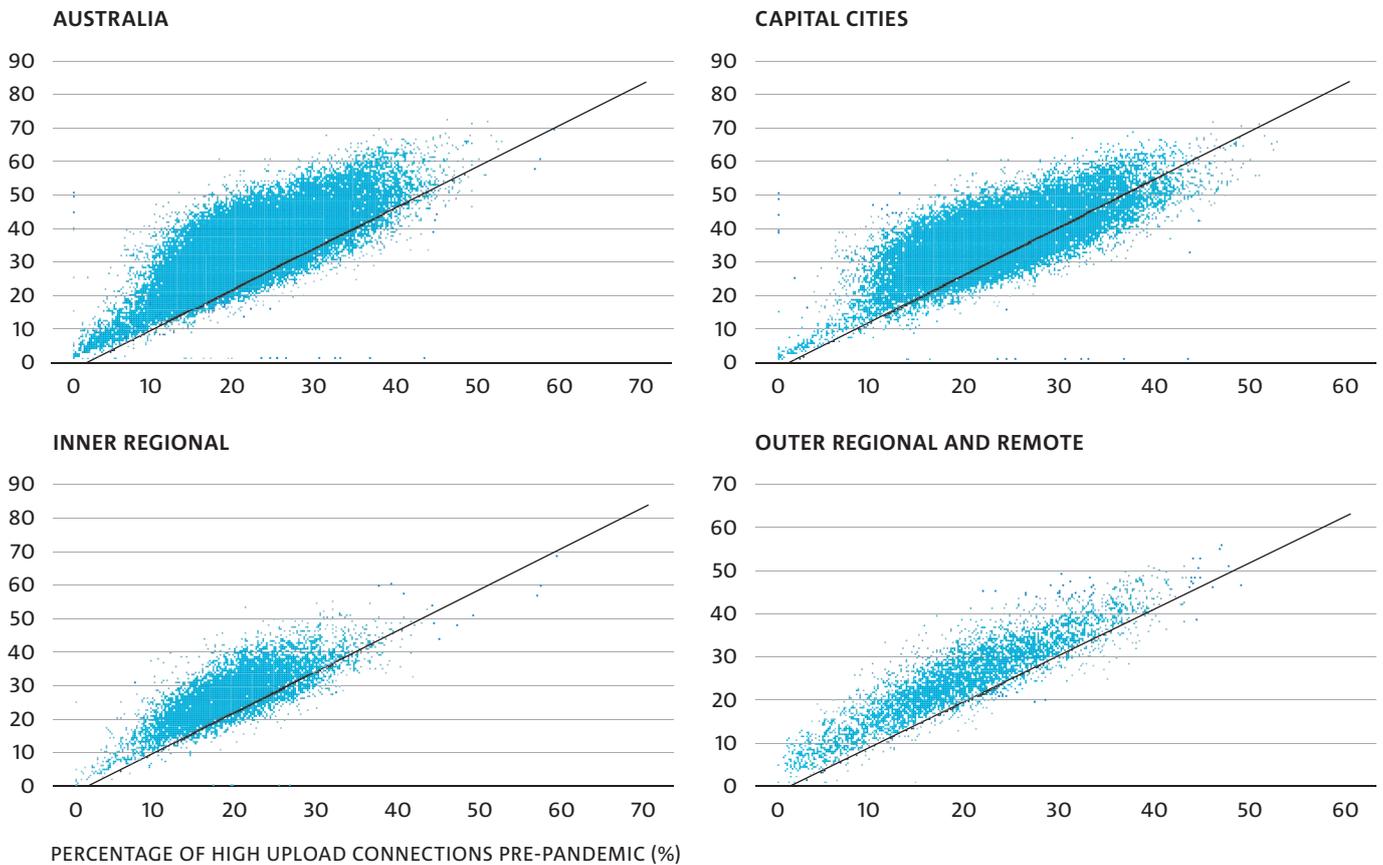


Figure 14: Percentage of households with high Sunday uploads during the initial pandemic peak compared to prior to the pandemic. Each dot represents a small local area (SA1). Distance above the 45° line indicates increase over pre-pandemic use.

4.2 Socio-economic disadvantage and online socialising

While most areas show evidence of increased connectivity during the pandemic there is considerable variation. To investigate this further we compared online social activity across areas according to their level of socio-economic disadvantage. The ABS's Index of Relative Socio-economic Disadvantage (IRSD) measures an area's level of relative disadvantage in terms of the incomes, employment, housing, health, and family circumstances of its population (ABS 2016n). Areas with low scores have high proportions of relatively disadvantaged people (it is important to note that this is a measure of the level of disadvantage in a given area, rather than of individual households). Appendix F provides the full list of variables captured in the index.

First, we tested whether socio-economic disadvantage was related to the adoption of online socialising in Greater Melbourne in the first lockdown (late-March to early-May 2020) and at the peak of the second lockdown (August 2020). Figure 15 shows the shares of Greater Melbourne households in each 'IRSD decile' (where 1 is the most disadvantaged and 10 the least) that had low, medium, and high Sunday uploads and no NBN connection during the two lockdowns (we estimated the total number of households by inflating 2016 Census household counts for subsequent population growth) (ABS 2016e). Figure 15 indicates that an area's relative socio-economic disadvantage had little effect on online socialising during the lockdowns, with the top and bottom IRSD deciles having similar upload patterns and similar rates of NBN coverage.

We then performed the same test on data pooled across all capital cities and regional (i.e. non-capital city) areas. The left panel of Figure 16 shows similar results to Melbourne above: in the capital cities socio-economic advantage had minimal effect on upload patterns during the first lockdown. In contrast, the right panel shows that in the regions socio-economic disadvantage had a large effect on online socialising, with households in areas in the low IRSD deciles having significantly lower Sunday upload levels than households in the high IRSD deciles.

We then explored whether socio-economic advantage/disadvantage has affected the persistence of people’s adoption of online socialising following the onset of the pandemic. Figure 17 compares the percentage of household NBN connections with high Sunday uploads in the most advantaged (top IRSD decile) and disadvantaged (bottom IRSD decile) areas since the start of 2020 in the major cities. The data indicate that greater online socialising has persisted for both groups, but more so for more socio-economically advantaged areas. The figure also shows that households in socio-economically disadvantaged areas of Brisbane and Perth did far less online socialising during and after the initial lockdown.

SHARE OF HOUSEHOLDS IN DECILE (%)

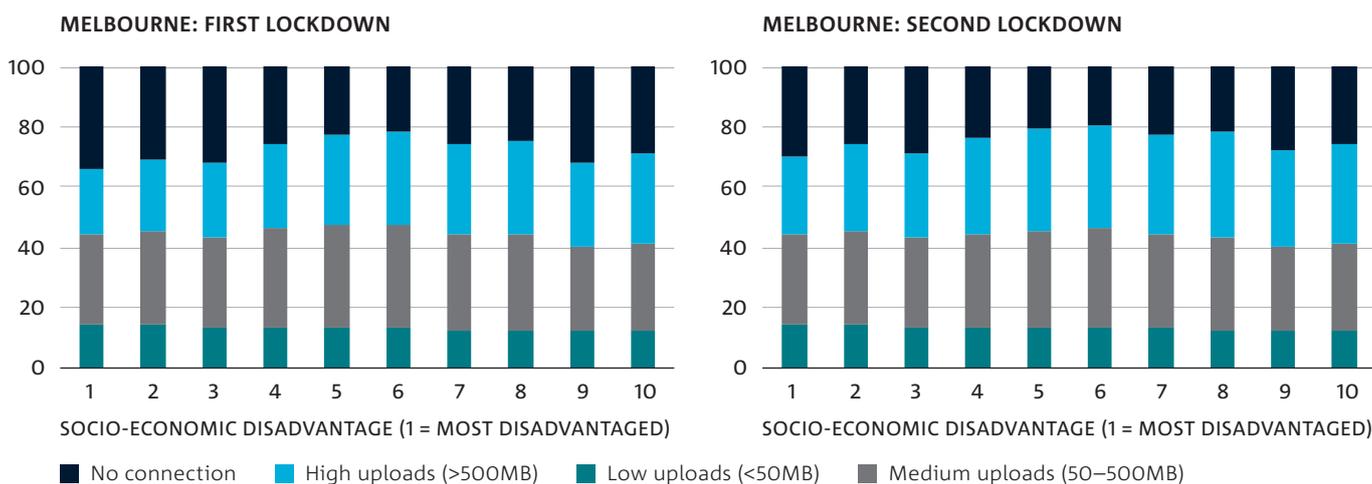


Figure 15: The percentage of Greater Melbourne households in each IRSD decile by Sunday upload level.

SHARE OF HOUSEHOLDS IN DECILE (%)

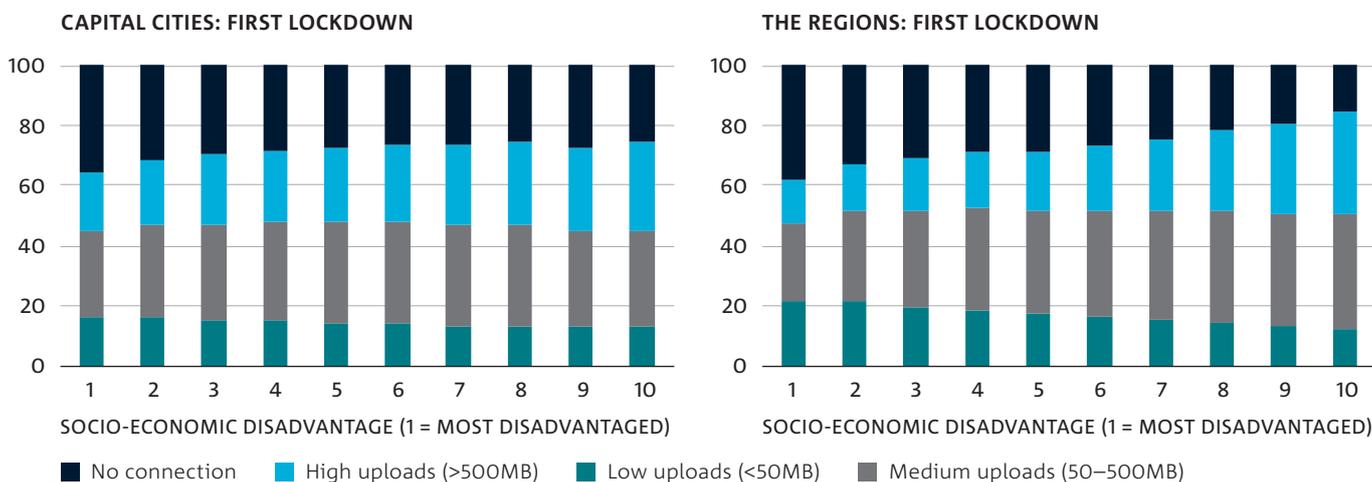


Figure 16: The percentage of capital city and regional (i.e. non-capital city) households in each IRSD decile by Sunday upload level.

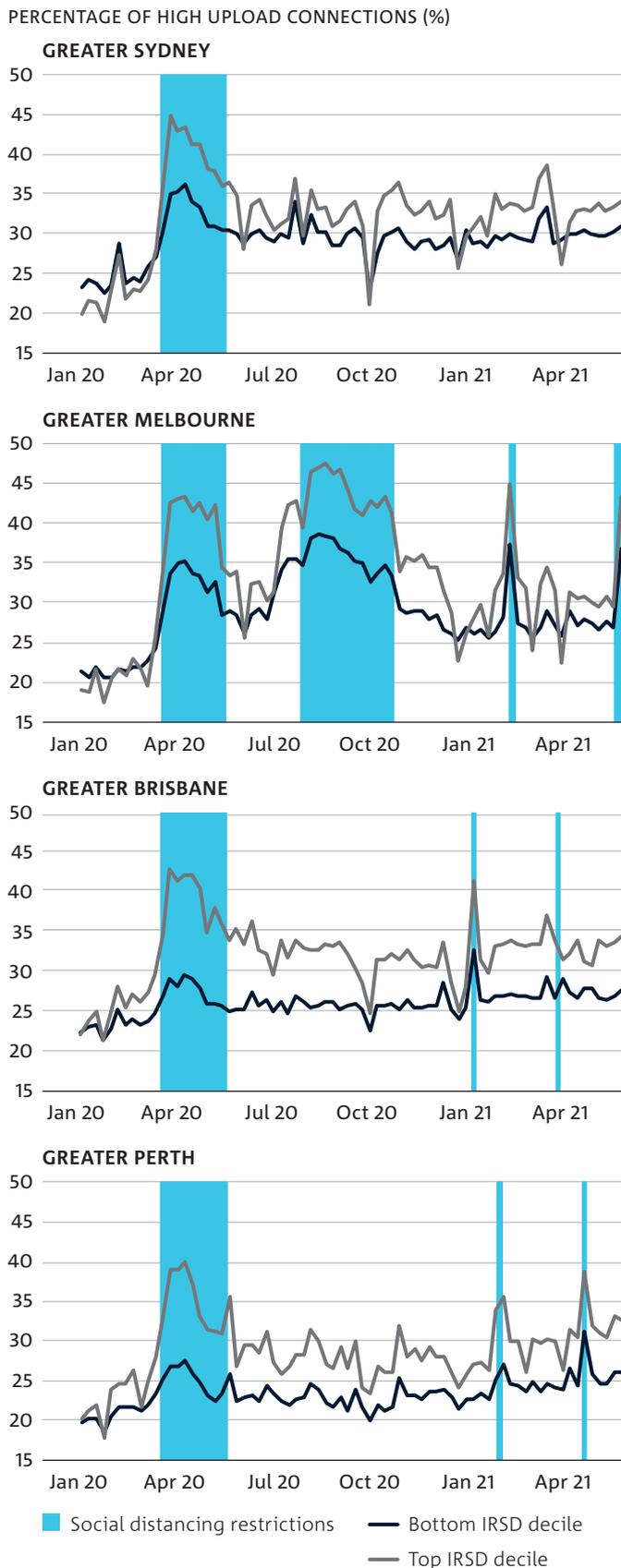


Figure 17: The percentage of household NBN connections with high uploads (>500MB) between 9am and 9pm on Sundays in SA1s in the bottom IRSD decile and top IRSD decile.

4.3 Predictors of low online social connectivity

While online interaction increased overall, there were still many households which did not show any evidence on online socialising on the Sundays covered in our dataset. There are likely to be many benign explanations for this, for example large households are in less danger of social isolation (the chance may be a fine thing!) while others may connect at other times or through other means. Nonetheless, identifying any demographic or socio-economic factors which predict low levels of connectivity may help to identify areas, and households, at risk of social isolation.

We developed a regression model to estimate the main contributors to an area's (SA1) level of social isolation during the initial lockdown, as measured by the percentage of connections with low (<50MB) Sunday uploads during the initial lockdown (averaged across Sundays in late-March to early-May 2020). Age proved a significant predictor. Increasing the percentage of the population aged 70+ from average (9%) to high (25%) increases the percentage of low upload connections from 21.5% to 32%. Decreasing the percentage of the SA1's population aged 70+ to low (2%) decreases the percentage of low upload connections to 15%. Location also had an effect, with low levels of Sunday upload activity more common among households in outer regional and remote areas.

The percentage of lone person households was also a good predictor of the percentage of connections with low Sunday uploads (more lone households = more low upload connections). This is somewhat concerning as lone people have very limited outside options to socialise during lockdowns, so this may suggest significant isolation. However, it is hard to disentangle from the effect of household size (i.e. households with more people are more likely to show higher activity as there are more people using the internet connection), so this is a question which would require household-level data to resolve (see Section 6). It is also important to note that online interaction is likely to be a highly imperfect substitute to in-person socialising, probably for more so than for remote work. One very recent study even suggests that virtual interaction can damage mental well-being (Hu and Qian 2021), perhaps by emphasising what people are missing.



5 Conclusions

The pandemic has brought enormous challenges, but to date Australia has shown remarkable resilience. Our digital infrastructure, including the NBN, has played a key role in this. The data described in this report show how millions of workers were able to continue working even while physically distanced from colleagues and clients. It also shows how most households increased their online social interactions as opportunities for in-person contact were curtailed. This will have mitigated the social and economic damage wrought by the pandemic, but it will also have helped the public health response by making it much easier (and less costly) for large numbers of people to stay at home.

This data allowed us to count the number of households interacting online, which provides a good proxy for working (on weekdays) or socialising (on weekends) from home. These estimates are consistent with those obtained by other methods such as ABS surveys and google mobility data. Levels of remote working increased sharply in March 2020, from a baseline of around 5% to 15–20% of households showing high levels of uploads during working hours, which is likely to equate to 30–40% of the labour force. However, reports of the death of the office are clearly greatly exaggerated, as the data indicate many remote workers returned as restrictions eased. A ‘new normal’ emerged from June 2020, with rates of working from home stabilising well above their pre-COVID levels.

There is considerable geographic variation in remote working which is largely explained by the number of office professionals, the most ‘teleworkable’ of occupations, within a region. Working from home was highest in Sydney and Melbourne, reflecting their greater proportions of office professionals in the workforce. Each jurisdiction followed a different path, reflecting different levels of COVID risk and associated public health restrictions. The ability to work from home is clearly highly elastic, as can be seen from the rapid spikes up and down associated with ‘snap lockdowns’ in a number of cities.

Within cities remote working also follows concentrations of office professionals; it is most persistent where more people were previously working from home, suggesting that the pandemic has (greatly) accelerated a pre-existing trend as technology offers opportunities to reduce travel for certain types of work. Areas with more middle-aged professionals, families with children and public transport users also showed greater telework persistence. Evidence is also emerging of a shift to regional areas on the fringes of our major cities, such as the Southern Highlands in NSW and the Sunshine Coast in Queensland. Such areas are likely to be highly attractive of office professionals able to use the ‘hybrid’ work model, attending city workplaces in person on just one or two days per week.

There was also widespread evidence of people increasing their online social activity, such as videocalling, as physical distancing restrictions were introduced. While this is likely to be easiest for more advantaged households with more digital devices, the data indicate that Sunday online interaction increased in virtually every corner of Australia. Again, this highlights how important our digital infrastructure has been in mitigating the social costs of COVID. Online interactions were lowest in areas with more older people, suggesting there may be an opportunity for digital literacy programs or technology provision to support those who currently miss out, though more fine-grained data would be required to confirm this.

The ability to work from home has been a vital assistance to Australian workers, employers and governments through the pandemic. For many of us the last 18 months would have been unthinkable without the digital technology and infrastructure that has only come into our lives relatively recently. However, it is also important to keep in mind that these benefits have been unevenly distributed, with remote office workers experiencing the pandemic very differently to those ‘essential workers’ who have had to keep moving, and those who have lost work entirely. Once we are finally able to look back on the pandemic it is very likely that it will appear as a sharp one-off increase in the level of remote working, and to a lesser extent online socialising. In the longer term this is likely to have profound consequences on where people choose to live and how they travel to and from workplaces, with significant implications for Australian society.



6 Further work

Traffic data from the NBN could have many applications in addressing social and economic questions of national, and local, importance. While (we hope) the COVID-19 crisis will soon be in the past, many of the changes it has wrought will persist, with significant implications for how, and where, we live, work and interact. The first, and most obvious, question is how the trends identified in this report continue to play out as the COVID-19 threat and associated restrictions wax and wane around the country. At the time of writing, Greater Sydney is locked down, a situation which appears likely to last for several months, and the fast-spreading delta variant may yet cause further havoc elsewhere. In the short term this will force a rise in remote working, schooling and socialising and in the longer run may prompt more workers to relocate.

There will be an opportunity to improve on the analysis presented here as data from the 2021 census become available (likely to be in 2022), as it will improve the accuracy of much of the socioeconomic and demographic data we have used. There is also an opportunity to work with the ABS to securely link NBN usage data with census microdata. This would give a direct indication of, for example, which occupations are continuing to work remotely, how households with children of different ages fare, whether lone households were isolated (i.e. had low uploads) during lockdowns and more. In contrast, our analysis has measured remote work and socialising in an indirect way, relying on spatial variation in NBN uploads and demographics, albeit at a very fine scale. In the meantime, surveys of NBN users might serve to address some of these gaps and more precisely calibrate our remote working estimates, particularly for those occupations which are harder to identify from aggregate data (e.g. clerical workers).

NBN Co's user surveys are another avenue for enhancing the analysis in this report. These surveys could be used to further validate our measure of remote work by asking users about their remote work behaviour and comparing the results to upload volumes. They could also be used to develop a more precise measure of remote work activity (e.g. persistent use for a certain number of hours per day). Finally, surveys could be used to monitor trends in regional remote work by asking the owners of new connections whether they have recently relocated to the region.

The most feasible and potentially high-impact follow-up would be to see whether those who continue to work remotely maintain their previous levels of interaction, or do they gradually become disconnected from colleagues who have returned to the office. It is possible, for example, that in a crisis remote work was adequate for maintaining ongoing projects and relationships, but it may be less suitable for establishing new ones, in which case we would expect to see a gradual decline in interactive activity for those still working from home. It is also possible that, as some return to the office, those who do not become somewhat marginalised. Declines in interaction may point to problems with teleworking and the importance of in-person attendance of workplaces. The absence of declines would point to the opposite. Such a study would be a significant advance in our understanding of the longer-term trajectory of remote working.

Appendix A

Household NBN upload data

The NBN data set contains each mesh block's count of households with low uploads (less than 50MB), medium uploads (50–500MB), and high uploads (over 500MB):

- during work time (9am–3pm) for each Wednesday between January 2020 and June 2021 (indicating remote working)
- in the 9am–9pm window on each Sunday between January 2020 and June 2021 (indicating social use).

Mesh blocks are the ABS's smallest geographic areas. There are 358,122 mesh blocks covering the whole of Australia, with most containing 30–60 dwellings (ABS 2016n). We aggregated mesh blocks containing fewer than 20 connections with others in the same SA1 into 'pseudo' mesh blocks to limit reidentification risk.

The counts in the initial NBN data set were of premises receiving general internet and standard data services (NBN Traffic Class 4), i.e. standard internet plans.

These premises are predominantly households but include some businesses. Since our focus is remote working and socialising by households, we removed all non-residential mesh blocks from the data set using the ABS's classification of mesh block types (ABS 2016n).

Appendix B

Validation of household upload volumes as a measure of remote working

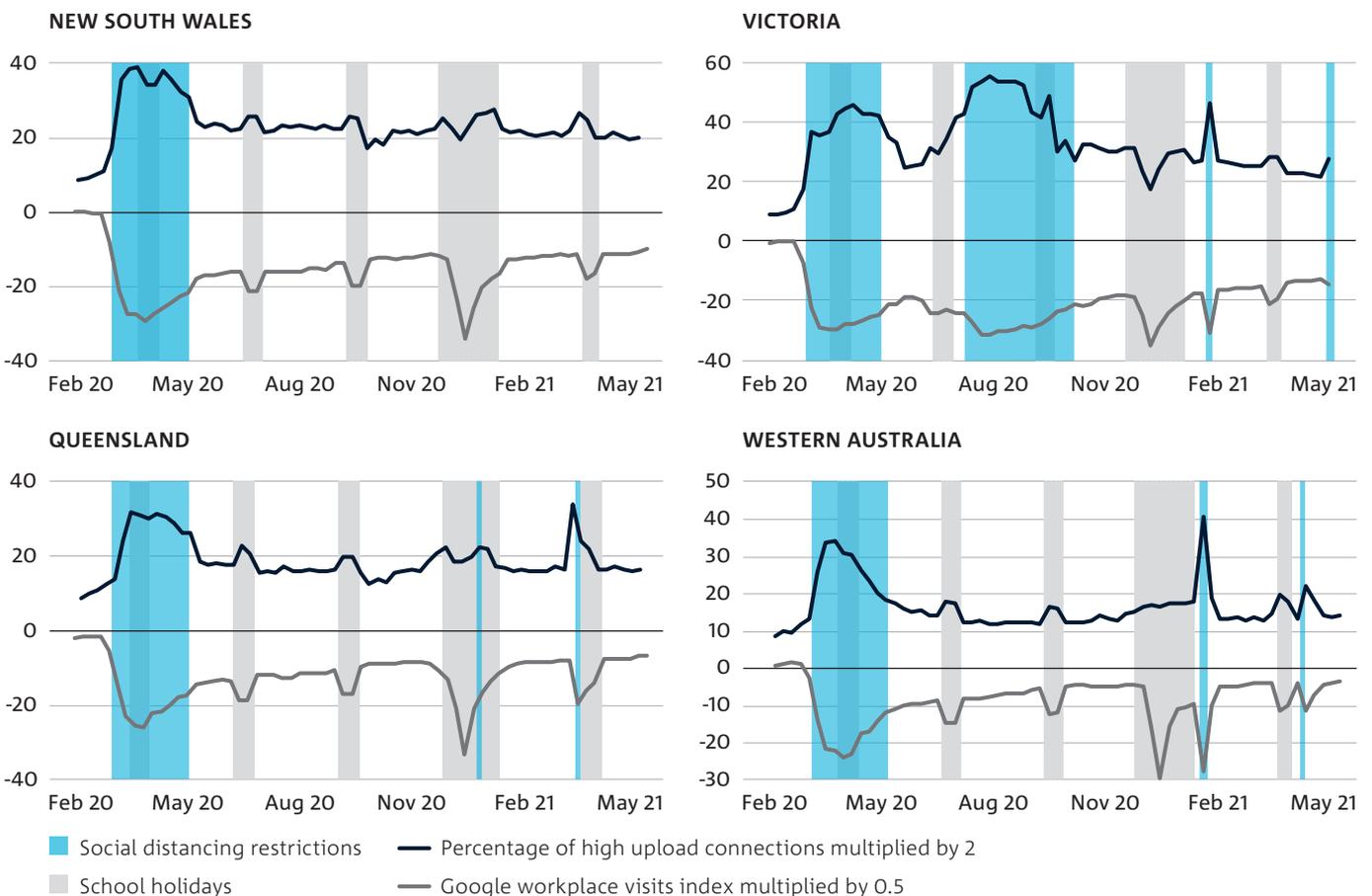
We have used each region’s percentage of household NBN connections with high uploads (>500MB) during work time (9am–3pm on Wednesdays) to measure the region’s level of remote work. Below we validate this measure against the Google mobility index of workplace visits, ABS survey data on the percentage of each state’s labour force working remotely, and the results of a survey on remote work from early in the pandemic.

B.1 Google mobility index of workplace visits

The Google mobility index of workplace visits measures changes in the number of workplace visits in a region relative to a January 2020 baseline (Google 2021). For example, an index value of -10% indicates a 10% decrease in the number of workplace visits compared to January 2020. Google collects the data for this index by tracking the movements of smartphones that have Google location services switched on (Google 2021).

The level of remote work within a broad region (such as a state) is inversely related to the region’s number of workplace visits (more people working from home leads to fewer workplace visits). Therefore, if the percentage of household NBN connections with high uploads during work time is a valid measure of remote work, then over time it should consistently move in the opposite direction to the workplace visits index. The figure below compares the two measures across all Wednesdays between January 2020 and May 2020 in the four largest states. Both measures have been rescaled for ease of visualisation (the percentage of high upload connections was multiplied by 2; the workplace visits index was baselined to zero in February 2020 and multiplied by 0.5). The figure shows that in each state the two measures have a strong inverse relationship, partially validating our measure of remote work.

RESCALED PERCENTAGE OF HIGH UPLOAD HOUSEHOLDS AND WORKPLACE VISITS INDEX (%)



It is worth noting that while these two quantities have a strong negative correlation, their absolute changes over time will differ. The index of workplace visits (in theory) measures the number of visits to all workplaces and covers all occupations. In contrast, the percentage of high upload connections during work time measures the remote work activity of a subset of occupations. Events such as large-scale lockdowns and changes in employment levels will have a different effect on each measure.

B.2 ABS surveys on the proportion of the labour force working remotely

The ABS's monthly Household Impacts of COVID-19 survey provides estimates (in some months) of the proportion of each state's labour force that worked from home all or most days per week, and the proportion that worked from home at least one day per week (but not most days) (ABS 2020a). This survey has incomplete coverage over space and time, giving estimates for:

- New South Wales and Victoria for February, September, October, and December 2020, along with February, April, and June 2021
- Queensland, South Australia, and Western Australia in December 2020 and February, April, and June 2021.

These estimates allow one to approximate the percentage of each region's labour force working remotely in each month as follows.

1. Assume that on average people who reported working from home 'all or most days per week' did so 4 days per week (it can only be 3, 4 or 5 days for a fulltime worker, for an average of 4), i.e. they worked remotely on 80% of their workdays.
2. Assume that in Victoria's strict second lockdown, people who reported working from home 'all or most days per week' did so 5 days per week.
3. Assume that on average people who reported working from home 'at least one' (but not most) days per week did so 1.5 days per week ('at least one but not most' can only be 1 or 2 days, for an average of 1.5), i.e. they worked remotely on 30% of their workdays.

4. Let $p_{most,t,r}$ and $p_{some,t,r}$ be the survey estimates of the proportions of the labour force working remotely most days per week and at least one (but not most) days per week respectively in month t and region r . Then the proportion of the labour force working remotely in month t and region r is given by

$$p_{remote,t,r} = 80\% \times p_{most,t,r} + 30\% \times p_{some,t,r}$$

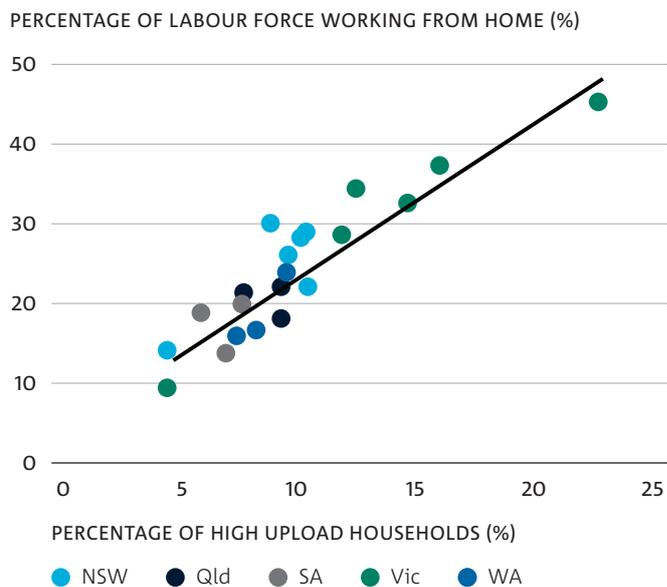
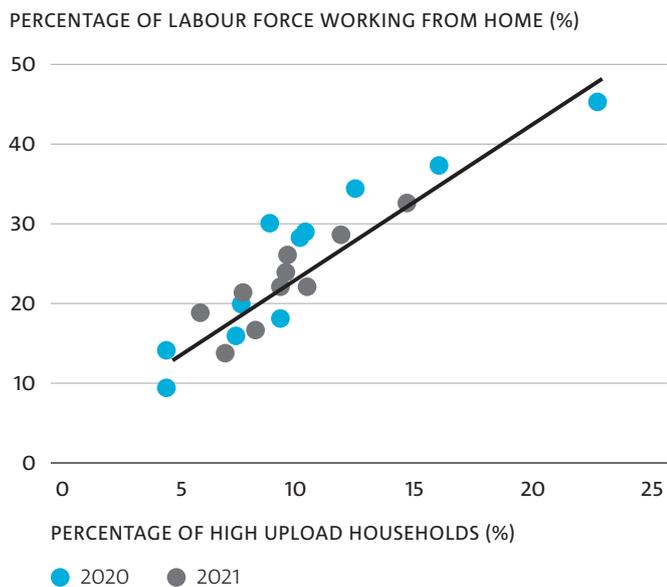
except during Victoria's strict second lockdown, where we have

$$p_{remote,t,r} = p_{most,t,r} + 30\% \times p_{some,t,r}$$

We used this method to estimate $p_{remote,t,r}$ for each month and region for which the ABS published $p_{most,t,r}$ and $p_{some,t,r}$. We then compared each $p_{remote,t,r}$ to the mean proportion of household NBN connections with high work time uploads across the Wednesdays in the corresponding month and region. The results are shown in the figure below. This figure indicates that a region's percentage of household NBN connections with high work time uploads is a good predictor of the percentage of the region's labour force working remotely. The equation for the fitted line is

$$perc_work_remotely = 0.04 + 1.95\ perc_high_upload$$

Therefore, a useful heuristic is that the percentage of the labour force working remotely is about twice the percentage of high upload connections during work time. The left panel shows that this relationship has remained constant over time, with the line providing a good fit for the data in 2020 and 2021 separately. The right panel shows that the line fits the data for each state reasonably well. Note that the small sample size (we only have 21 observations) and the large margins of error in the ABS estimates of the proportion of the labour force working remotely (around +/-5 percentage points) make it necessary to pool all regions' data to fit the model.



B.3 Survey on remote work early in the pandemic

Beck et al. (2020) surveyed a sample of around 1,000 Australians about their remote working behaviour at two points early in the pandemic. Their survey results indicate that about 20% of respondents worked remotely on any given workday before the pandemic. This increased to about 56% at the start of the pandemic (30 March–15 April) and then decreased to about 50% a few weeks later (23 May–15 June). These estimates clearly overstate the true percentage of workers working remotely, which can only ever reach about 40% due to the occupational composition of the Australian workforce (only so many jobs can be worked from home). This overstatement is most likely due to their heavy over-sampling of clerical and managerial occupations. Nevertheless, the timing and magnitude of these changes are in line with changes in the percentage of household NBN connections with high uploads during work time: low before the pandemic, a spike at the start of the pandemic, and then a decline a few weeks later.

Appendix C

Trends in remote working before the pandemic

The limited information available on remote working trends before the pandemic indicates mild increases in remote work over recent years.

- The Australian Census asks respondents about their mode of transport to work on Census day. In the 2011 Census 4.9% of respondents that worked on Census day reported working from home (ABS 2011). This figure increased to 5.3% in the 2016 Census (ABS 2016a).
- The ABS's Working Arrangements Survey indicates that the percentage of workers that regularly work from home increased from 30% in August 2015 to 32% in August 2019 (ABS 2020b). To be consistent with the above Census statistics, the 'regular' work from home reported in this survey must equate to once every 5–6 days on average.
- The ABS's Household Impacts of COVID-19 Survey asked respondents about their work from home behaviour before the pandemic (ABS 2020a). 12.5% of workers reported working from home all or most days, and 11.1% of workers reported working from home at least once (but not most days) per week. This translates to 6.7% of workers working from home on any given day, assuming that on average 'most days' means 4 days per week and 'at least once (but not most days) per week' means 1.5 days per week.

Appendix D

Definitions

D.1 Potential teleworker

Figure 5 gives each region's share of Australia's workers and potential teleworkers to highlight the importance of the major cities. We defined a potential teleworker as any worker in the following ANZSCO level two occupational groupings (ABS 2019a):

- Managers: Chief Executives, General Managers and Legislators; Specialist Managers.
- Professionals: Arts and Media Professionals; Business, Human Resource and Marketing Professionals; Design, Engineering, Science and Transport Professionals; ICT Professionals; Legal, Social and Welfare Professionals.
- Clerical and Administrative Workers: all level two ANZSCOs.

In arriving at this definition of a potential teleworker, we reviewed the detailed descriptions of ANZSCO classes (ABS 2006) and determined that the above occupational groups are highly conducive to remote working, as they typically involve working with information in an office setting (something that can be reasonably well approximated at home).

D.2 Office professionals

In our modelling we found that the percentage of a region's population working in certain office-based occupations was highly predictive of the region's percentage of household NBN connections with high uploads during work time (i.e. telework level). These occupations are the following ANZSCO level two groups (ABS 2019a):

- Managers: Chief Executives, General Managers and Legislators; Specialist Managers
- Professionals: Arts and Media Professionals; Design, Engineering, Science and Transport Professionals; ICT Professionals; Legal, Social and Welfare Professionals

Workers in these occupations tend to have high uploads during work time, indicating high levels of online interaction (video meetings etc.).

We used the percentage of a region's population working as office professionals (i.e. working in the above occupations) as a predictor of the region's telework level in several of our models. Figure 8 shows the spatial distribution of this percentage across the SA3s in the major cities.

D.3 Inner and outer suburbs

Figure 9 shows the percentage of household NBN connections with high work time uploads in the inner city and outer suburb regions of Sydney, Melbourne, and Brisbane. Here, we have defined the inner city regions as the SA3s Sydney Inner City, Melbourne City, and Brisbane – Inner, and have defined the outer suburb regions as all other SA3s in the Greater Capital City Statistical Area (ABS 2016c).

Appendix E

Models

E.1 Overview

We specified regression models to test a range of hypotheses about remote working and online socialising in the pandemic. Our models seek to explain regional variation in the level of remote working or online socialising in terms of regional variation in demographics.

In sampling regions to fit each model, we excluded regions where the number of NBN connections exceeded the number of households according to the 2016 Census (from which our demographic data are drawn). These regions are likely to have grown significantly since 2016, making the demographic data from the 2016 Census inaccurate.

Our general modelling framework involves using linear regression models to relate the j th region's percentage of high upload households in period t (Y_{jt}) to the region's socioeconomic characteristics. Formally, the models take the form

$$Y_{jt} = \beta_{0t} + \sum_{k=1}^J \beta_{kt} X_{jk} + \epsilon_{jt}$$

where X_{jk} is a socioeconomic measure of the j th region, such as the percentage of the population that works in occupation z , and ϵ_{jt} is a Gaussian error. In this example, the weight β_{kt} gives the effect of a one unit increase in the percentage of the region's population working in occupation z on the region's percentage of high upload households, controlling for the other predictors. This provides information on whether X_{jk} is an important determinant of remote working.

We are interested in the weights β_{kt} at different points in time. For example, to test whether different occupations were using the NBN to work remotely at the pandemic's peak, we fit the model to data from May 2020. Then to test whether different occupations were persisting with remote working later in the pandemic, we fit the model to data from May 2021.

All socio-economic and demographic data for these models were sources from Census TableBuilder (ABS 2016b; ABS 2016d-i; ABS 2016k-m; ABS 2016q) and the ABS SEIFA tables (ABS 2016o-p).

E.2 Jurisdictional differences in remote work

Figure 4 relates community transmitted COVID cases in each jurisdiction to 31 May 2021 to jurisdictional differences in working from home in May 2021 beyond what can be explained by occupational and demographic differences (COVID Live 2021). The figure's vertical axis shows the effect of jurisdiction on the average (in terms of demographics) SA2's percentage of connections with high uploads in May 2021, with NSW set as the baseline. We estimated these effects via the following methods.

1. We regressed (at the SA2 level) the mean percentage of connections with high work time uploads in May 2021 on:
 - office professionals as a percentage of the SA2's population (interacted with jurisdiction indicator variables to allow the weights to vary by jurisdiction)
 - the SA2's mean percentage of high upload connections in February 2020 (again interacted with jurisdiction indicators to allow the weights to vary by jurisdiction)
 - a variable indicating whether the SA2 is in a major city
 - the SA2's mean household size.

Note that in fitting the model we excluded upload data from the weeks in May 2021 where Perth and Melbourne had their respective short lockdowns (and spikes in remote work).

2. We computed (across all SA2s) the mean for office professionals as a percentage of the population and the mean percentage of high upload connections in February 2020.
3. We substituted these means into the fitted model to compute the jurisdictional differences in remote work for the average SA2.

Including additional demographic factors in the models had minimal effect on the results.

E.3 Relative level of remote work by occupation

We used a regression model of the form in section 11.1 to estimate the relative levels of remote work by workers in different occupations at the initial peak of the pandemic. Our set of occupations contained the 41 ANZSCO level 3 occupational groupings that could conceivably be worked from home (identified by reviewing the ANZSCO occupation descriptions). It also contained one broad group housing all remaining occupations, i.e. those that could not be worked from home (labourers, drivers, trades workers etc.).

The model had the following structure.

- The response variable was the SA1's mean percentage of household NBN connections with high uploads during work time across the Wednesdays in May 2020.
- The predictors were the percentage of each SA1's population working in each of our 42 occupational groups.
- The control variables were:
 - dummy variables for state/territory
 - dummy variables for the remoteness of the location (city, inner regional, outer regional, remote)
 - the percentage of the SA1's population that is employed
 - primary, secondary, and university students as percentages of the SA1's population
 - people 70 years and older as a percentage of the SA1's population
 - the SA1's mean household size (i.e. number of people).

The regression weight for each occupation gives the effect of a one percentage point increase in the proportion of the SA1's population working in that occupation on the SA1's percentage of high upload NBN connections during work time.

- A positive weight indicates that workers in the occupation worked remotely via the NBN (i.e. had high work time uploads); a large positive weight indicates that many of them did so.

- We specified the model so that the group containing all occupations that could not be worked from home had a weight of zero (omitted the group from the model, making it the baseline)
- A zero or negative weight indicates that workers in the occupation showed no evidence of working remotely via the NBN. That is, their work time upload levels were small and indistinguishable from non-teleworkers.

Figure 7 shows the relative telework levels of the different occupations estimated via this method. All negative weights have been set to zero.

E.4 Persistence of remote work by occupation

We measured the persistence of remote work in each occupation via the following method.

1. Fitting the regression model above to data from May 2021. That is, the response variable became the SA1's mean percentage of household NBN connections with high uploads during work time across the Wednesdays in May 2021. We excluded the week of Victoria's lockdown and associated spike in remote work.
2. Obtaining the ratio of each occupation's regression weight in May 2021 to its regression weight in May 2020. This ratio indicates the degree to which workers in the occupation have persisted with remote work between May 2020 and May 2021.

We excluded the (few) occupations that showed no evidence of remote work in May 2020 from this analysis (as we were unable to calculate persistence scores for them).

E.5 Socio-economic aspects of persistent remote work

Section 3.3 discusses the socio-economic factors associated with the persistence of remote work. This discussion is based on estimates from a regression of each SA2's mean percentage of household NBN connections with high uploads during work time across the Wednesdays in May 2021 (excluding the week of Melbourne's short lockdown) on the SA2's socio-economic characteristics. We fitted this regression model separately to each major city; the table below provides the estimated weights. We did not fit the model to the other cities as they contain an insufficient number of SA2s to reliably estimate the regression weights.

VARIABLE (SA2 CHARACTERISTIC)	SYDNEY	MELBOURNE	BRISBANE	PERTH	ADELAIDE
Intercept	-0.04	-0.03	0.03	0.00	0.02
Proportion of connections with high work time uploads in February 2020	0.78***	0.68***	0.75***	0.86***	0.83***
Proportion of population working as office professionals	0.38***	0.42***	0.34***	0.25***	0.20***
Proportion of office professionals commuting via public transport	0.03***	0.08***	0.03*	0.04***	0.02
Mean commute distance of office professionals	0.00	0.00	0.00	0.00	0.00
Proportion of office professionals aged 30–49	0.04***	0.06***	-0.01	0.00	0.01
Couples with children as a proportion of all households	0.07***	0.07***	0.08***	0.03***	0.03
Index of Economic Resources percentile	0.00	0.00	0.00	0.00	0.00
Proportion of households with a spare bedroom	0.04***	<0.00	-0.04**	0.00	-0.02
Observations (SA2s)	298	302	226	151	101
R-squared	0.86	0.88	0.83	0.90	0.77

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

E.6 Regional remote work

Section 3.6 discusses the regional areas of NSW and Queensland that had greater percentages of high upload connections during work time in May 2021 than that expected based on their demographics relevant to NBN use. We identified these areas via the following method.

- We selected the region of interest: regional NSW (all areas of NSW outside the Greater Sydney region) or regional Queensland (all areas of Queensland outside the Greater Brisbane region).

The fitted values from this model gave each SA3's expected mean percentage of high upload connections in May 2021 based on its values for the above variables.
- Across all SA3s in the region of interest, we regressed the mean percentage of NBN connections with high work time uploads across the Wednesdays of May 2021 on:
 - the mean percentage of NBN connections with high work time uploads in February 2020
 - the mean percentage of NBN connections with high work time uploads in August 2020
 - office professionals as a proportion of the population.

A positive residual indicates that the SA3's level of telework in May 2021 was higher than expected, potentially due to an influx of office professionals. The short timespan (August 2020 to May 2021) means we only observe relatively small effects; any trend would become more visible over longer periods.

The table below provides the estimated weights for regional NSW and regional Queensland.
- We obtained the model's residual for each SA3.

VARIABLE (SA3 CHARACTERISTIC)	REGIONAL NSW	REGIONAL QLD
Intercept	-0.01	0.00
Proportion of connections with high work time uploads in February 2020	0.92***	0.32*
Proportion of connections with high work time uploads in August 2020	0.31***	0.67***
Office professionals as a proportion of the population	0.19**	0.13
Observations (SA3s)	41	42
R-squared	0.88	0.93

E.7 Predictors of low online connectivity

Section 4.3 discusses the main contributors to an area's (SA1) level of social isolation during the initial lockdown. This discussion is based on estimates from a regression of each SA1's percentage of connections with low (<50MB) uploads in the 9am-9pm window on Sundays during the initial lockdown (averaged across the Sundays in late-March to early-May 2020) on the SA1's socio-economic characteristics. The table below provides the estimated regression weights. Most of the discussion in section X is based on model 1.

VARIABLE (SA1 CHARACTERISTIC)	MODEL 1	MODEL 2	MODEL 3
Intercept	0.27	0.17	0.02
Index of Relative Socio-economic Disadvantage percentile	-0.01***	-0.01***	-0.01***
Outer regional or remote area indicator	0.06***	0.06***	0.03***
Inner regional area indicator	0.02***	0.03***	0.01***
Proportion of the population aged 70 years and over	0.62***	0.49***	0.11***
Mean household size	-0.05***	-0.02***	-0.04***
Lone person households as a proportion of all households	–	0.52***	0.15***
Mean proportion of connections with low uploads (<50MB) on Sundays in February 2020	–	–	0.67***
Observations (SA1s)	44,026	44,026	44,026
R-squared	0.56	0.61	0.85

Appendix F

SEIFA

The IRSD and IER SEIFAs are weighted averages of many variables representing the different dimensions of socio-economic advantage and disadvantage (ABS 2016n). The table below lists the variables included in each index.

SOCIO-ECONOMIC VARIABLE	IRSD	IER
Percentage of people on low incomes	✓	✓
Percentage of families with children under 15 years of age who live with jobless parents	✓	
Percentage of occupied private dwellings with no internet connection	✓	
Percentage of people aged 15 years and over whose highest level of education is year 11 or lower (includes Certificate I and II)	✓	
Percentage of people (in the labour force) unemployed	✓	✓
Percentage of people classified as labourers	✓	
Percentage of occupied private dwellings paying rent less than \$215 per week (excluding \$0 per week)	✓	✓
Percentage of one parent families with dependent offspring only	✓	✓
Percentage of people aged under 70 who have a long-term health condition or disability and need assistance with core activities	✓	
Percentage of people aged 15 and over who are separated or divorced	✓	
Percentage of employed people classified as machinery operators and drivers	✓	
Percentage of employed people classified as low skill community and personal service workers	✓	
Percentage of occupied private dwellings with no cars	✓	✓
Percentage of occupied private dwellings requiring one or more extra bedrooms	✓	✓
Percentage of people aged 15 years and over who have no educational attainment	✓	
Percentage of people who do not speak English well	✓	
Percentage of occupied private dwellings who are lone person occupied private dwellings		✓
Percentage of occupied private dwellings who are group occupied private dwellings		✓
Percentage of occupied private dwellings owning dwelling without a mortgage		✓
Percentage of dwellings with at least one person who is an owner of an unincorporated enterprise		✓
Percentage of people with stated annual household equivalised income greater than \$78,000		✓
Percentage of occupied private dwellings owning dwelling (with a mortgage)		✓
Percentage of occupied private dwellings paying mortgager greater than \$2,800 per month		✓
Percentage of occupied private dwellings with four or more bedrooms		✓

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