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Analysing the impact of COVID-19 on urban transitions and urban-regional dynamics in Australia*

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In this paper, we draw on insights from economic theory on urban growth, large shocks and spatial dynamics to assess COVID-19 flow-on effects and potential disruptive legacy in urban-regional dynamics. Urban dynamics in Australia are assessed at national, regional and intra-urban scales. Long-term and short-term urban dynamics are analysed against random growth, locational fundamentals and increasing returns theories of urban growth and adjustment. A focus in Australia and elsewhere is the potential effect of COVID-19 on where people want to live, enabled in part by technological connectivity that releases some workers from proximity to work constraints when choosing a home. Our results suggest that urbanisation trends and adjustments to shocks differ for capital cities and noncapital cities. At the inter-regional migration level, Australia's largest urban system, Sydney, is characterised by a cointegration relationship between outmigration and Sydney property prices relative to other housing markets. At finer spatial scales, COVID-19 had a negative impact on house prices within Sydney and may, for some micro-geographies and/or towns and regional centres, lead to significant change. However, typically this effect on houses (not units) began to dissipate in the period June–November 2020, when also controlling for housing policy pre- and post-COVID-19.

Key words: housing markets, increasing returns, locational fundamentals, random growth, regional migration, teleworking, urban transitions.

1. Introduction

Our way of life was rapidly changed in response to the 2020 COVID-19 pandemic. Prior to its onset, Australia experienced a population boom from both temporary and permanent residents, especially its most populous cities of Sydney and Melbourne. In the intercensal period, capital cities grew twice as fast as noncapital cities, reflecting a trend towards urbanisation that has persisted over much of the 20th Century (Davison, 1993; Frost & O'Hanlon, 2009). In this paper, we ask what insight might be gained from Australian

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urban dynamics in the past century with respect to any enduring disruptive legacy in the interaction of urban and regional areas resulting from COVID-19?

Throughout 2020–2021, there are indications that where some people choose to live, and the way they work, is reshaping the urban-regional interactions by altering the relationship between location of home and location of work (Fulton, 2020; Lennox, 2020). Regional house price appreciation provides one indicator of this (CoreLogic, 2021).

However, the effects of COVID-19 also sit on top of existing social, economic and technological ‘slow-burn’ drivers of urban dynamics. These changes affect the types of cities and towns, including regional, mining and agricultural communities, differently. For instance, automation of jobs is expected to pose a greater risk to lower-educated (often routine) and less urbanised centres. Conversely, digitalisation and telecommuting may induce higher skilled workers from more urbanised areas to relocate outside larger cities (OECD, 2020) and spur further amenity migration. The fundamentals of these changes were evident before COVID-19, but may accelerate with wider acceptance of different working practices and digital infrastructure to support this. Relative house price appreciation driven by income-rich households relocating to high-amenity commutable country towns and seaside locations during 2020 is an indicator of this shift.

Analysis of historic shocks to urban systems caution against expecting too much change – *as a consequence* of temporary shocks. Recent studies have examined the impact of large exogenous shocks to the distribution of economic activity and intercity population distribution typically finding a high degree of mean reversion/path resumption over time (Bosker et al., 2007; Davis & Weinstein, 2002). A key driver of this is increasing returns in cities via agglomeration economies (Duranton & Puga, 2015; Glaeser & Gottlieb, 2009), but also the market potential of cities as places of leisure and consumption, neighbourhood amenity, social status and interaction (Glaeser et al., 2001; Nygaard & Meen, 2013). Each of these ‘centripetal’ dynamics for urbanisation are in turn offset by ‘centrifugal’ dynamics, such as congestion costs, declining housing affordability and/or aspects of liveability. Mean reversion may also be spurred by reactive policy paradigms seeking to ‘revert to normal/precrisis status quos’. In Australia, housing policy is central to institutional economic responses attempting to provide expedited paths to recovery.

Predicting the future trajectory out of crisis is thus uncertain. Firstly, it can be difficult to separate the effect of shocks from other, underlying and potentially enduring or ‘slow-burn’, dynamic determinants of urban transitions. Secondly, insufficient data yet exist that capture people’s behaviour in a post-COVID-19 era. Third, the mitigation of exogenous shocks through public policy responses blurs the identification of impacts of shocks themselves.

In analysing the potential impact of COVID-19 for Australian cities and urban-regional interactions, we use historic and contemporary data to identify the nature of Australia's urban and intra-urban growth patterns, and the implication for enduring effects arising from temporary shocks. The analysis is conducted across the national urban system, and inter- and intraregional urban dynamics in Sydney. The remainder of this paper is divided into 4 sections. Section two briefly details competing conceptual approaches to framing the 'our cities will, will not' substantially change hypothesis as a result of COVID-19 analysis. We here draw on theories of urban growth following shocks. Section three provides methodological details and empirical results from Australian urban dynamics in a long-term (1911–2016), medium-term (2002–2020) and short-term (2020) perspectives. The short-term perspective focuses on Sydney and does not capture the renewed lockdown conditions introduced in July 2021. Section five concludes and discusses implications for urban transitions, and urban-regional interactions, in Australia following COVID-19.

2. Urban growth theories and shocks

There is a considerable literature explaining the functions, persistence and growth of cities (e.g. Davis, 1965 [2015], Bairoch, 1988), and the location of different types of city dwellers within cities shaped by space-access models and social interactions (e.g. Alonso, 1964; Durlauf, 2006; Rosenthal & Ross, 2014). Agglomeration and increasing returns, as well as locational (geographic) advantages and urban amenities, provide important central economic explanations (e.g. Davis & Weinstein, 2002; Duranton & Puga, 2015; Glaeser & Gottlieb, 2009; Glaeser et al., 2001; Krugman, 1991a). In this literature, economic processes often generate path dependencies that condition urban developments over long periods of time (Rosenthal & Ross, 2014). Alongside the economic determinants, amenity-based determinants are increasingly important in explaining demand for living in cities (Glaeser et al., 2001) and living in locations with natural amenities, such as 'sunbelt' areas (Bohnet & Pert, 2010; Glaeser & Gottlieb, 2009; Gurran & Blakely, 2007). Lee and Lin (2017) show that natural environment characteristics can contribute to anchoring areas' social status to development trajectories. Nygaard and Meen (2013) show that historic infrastructure investment contributes to lock-in of urban social structures.

A more recent literature analyses the impact of shocks on urban development trajectories. In this literature, increasing returns and locational advantage in many cases become forces for mean reversion following temporary (Bosker et al., 2007; Davis & Weinstein, 2002) and permanent shocks (Bleakley & Lin, 2012; Michaels & Rauch, 2017), although physical shocks can also act as catalysts for place-specific change (Hornbeck & Keniston, 2017).

In this paper, we conceptualise COVID-19 as a shock to the urban system, one that potentially conditions where and why people want to live in particular locations. Explicitly and implicitly, therefore, competing views of what will happen post-COVID-19 engage with the issue of how urban structures evolve following shocks.

While the pandemic itself is likely to be a temporary shock, a ‘cities will change (as a result of C19)’ argument assumes that a temporary exogenous shock is generating a permanent behavioural adjustment. This perspective links to ideas around a ‘new normal’ emerging from a change in preferences, values and behaviours. This argument links to random growth theory (RGT) – in response to shocks, cities change trajectory (until a new shock emerges).

Conversely, a ‘cities will not change (as a result of C19)’ argument assumes that a temporary shock is insufficient to alter the underlying dynamics of urban growth and spatial patterns. This argument links to locational fundamentals theory (LFT) and increasing returns theory (IRT) – in response to shocks, cities only temporarily change trajectory, before economic determinants of urban growth begin to reassert themselves.

Given policy and public interest in the impact of COVID-19 on Australian cities, we commence our discussion of growth theories with the random growth theory (RGT). The RGT accounts for an important empirical regularity of city size distribution (known as Zipf’s Law), although it has no economic rationale or foundation (Krugman, 1996). From the perspective of urban growth, RGT holds that a system of cities with very different sizes can emerge from a stochastic process of shocks over time. For instance, when subjected to a temporary shock, the trajectory of urban growth and structures permanently change (until the next shock). Under the RGT, the dynamic distribution of cities over time is independent of its initial size (Simon, 1955).

According to Gabaix (1999), Zipf’s Law for a system of cities necessarily emerges in the upper distribution of cities when the effects of industrial diversification become negligible for cities above a certain size. Gabaix postulates that the growth rate of cities is a composite growth:

$$g_{i,t} = \underline{g} + g_{i,t}^{pol} + g_{i,t}^{reg} + g_{i,t}^{sec}, \quad (1)$$

where g is the growth rate of city i at time t ; \underline{g} is the country mean growth rate and $g(\cdot)$ is growth rate determined by city policy (e.g. planning, infrastructure), regional macroeconomic factors and sectoral economic factors.

The growth rate of cities in Australia post-COVID-19 cannot yet be established. One impact of COVID-19 is hypothesised to lead to greater demand for regional, peri-urban and potentially suburban locations. This argument is driven by a greater incidence of teleworking during the pandemic and a continuation of this trend following the pandemic. In adjusting to teleworking, demand for larger properties and properties with outdoor space becomes more attractive, compared to smaller and often more densely built

inner-city properties (CoreLogic, 2021). This trend is reinforced by the nature of COVID-19 transmission where proximity and closeness (population density) increase the risk of transmission and death. For instance, Wu et al. (2020) find that population density and long-term exposure to lower air quality ($pm_{2.5}$) from living in denser, more urbanised, areas increase the risk of mortality in US data. Under RGT, these changes in patterns of housing demand are expected to be enduring (until the next shock).

A variant on the RGT is the locational fundamental theory (LFT) (Davis & Weinstein, 2002). Rather than city growth being random, it is the distribution of geographic, natural and economic characteristics of locations that is random. Under the LFT, the size and distribution of cities is determined by the scale and importance of locational advantages. Consequently, an urban systems of very different sizes again emerge. Zipf's Law also emerges under the LFT, but unlike under RGT where the size characteristics of individual cities is changeable, individual city size characteristics is less changeable under LFT. Under *ceteris paribus* conditions, the LFT would predict that areas in the short and medium term revert to their historic economic trajectory following shocks to urban structures.

For instance, cities and urban centres may have specific locational characteristics that generate economic and/or residential attractiveness. Transport-related locations (e.g. ports, rivers), but also geography and environmental amenities (e.g. sunbelts), may thus condition the distribution of economic activity and quality of life (Rappaport & Sachs, 2003). Growth trajectories and spatial patterns may deviate from long-term trends in relation to economic shocks or housing affordability pressures, but the presence of locational characteristics is expected to, over-time, generate mean reversion, or resumption of growth patterns. Regional, peri-urban and suburban locations may in this regard become more attractive if home buyers attempt to avoid areas particularly exposed to shocks, but would under LFT be expected to recover postshock. Notably, the attractiveness of locational fundamentals can change in response to technological or societal change. In Australia, a trend towards the sunbelts of the eastern seaboard is evident since the 1970s (Bohnet & Pert, 2010).

The presence of locational characteristics may also serve as an impulse for initial agglomerations of people and economic activity that subsequently become self-reinforcing clusters due to the existence of external economies and initial concentrations. In Australia, the early settlement on ports was fundamental to trade flows and immigration (McCarthy, 2005), and capital cities soon became the administrative, cultural and economic centres of each colony city-state (Marsden, 1997). In the contemporary period, capital cities remain nodal hubs of globally connected finance and symbols of international dominance attracting new investment opportunity.

The increasing returns theory's (IRT) explanation of distribution of population and economic activity arises from the existence of agglomeration/external economies, nonmarket interactions (social interactions,

neighbourhood effects) and spillovers (Fujita & Thisse, 1996; Glaeser, 2010), or increasing returns to scale, pecuniary externalities arising from scale economies (Krugman, 1991a). Spatial urban structures are then determined by centripetal (agglomeration economies, urban amenities) and centrifugal (transport costs, housing affordability) forces.

In standard urban economics models, households face a trade-off between access to agglomeration benefits (higher wages, amenities) and congestion cost (commuting and housing). The distribution of where households live is a function of the income elasticity of housing demand relative to the income elasticity of marginal valuation of commuting time (Muth & Goodman, 1989). If the income elasticity of housing demand exceeds the latter elasticity, then higher income groups tend to relocate to more peripheral locations. However, endogenous (for instance resulting from income agglomeration, or interdependent household preferences (Evans, 1976)) and exogenous factors (for instance natural amenities) can result in micro-geographies of advantage and disadvantage that do not conform to an overall (or average) trend in the distribution of income (Brueckner et al., 1999). Cities thus exhibit overall patterns of centripetal and centrifugal dynamics, as well as micro-geography-based patterns that both can generate path dependence.

Unlike locational advantage, under IRT concentrations of people and economic activity can be altered. Policy, social or physical shocks (e.g. earthquakes, wars) can alter the nature of agglomerations. Importantly, the extent to which shocks lead to permanent changes is then a function of the magnitude of shocks and the strength of any remaining agglomeration forces. Evidence on intra-urban social structures from the UK suggests that even substantial interventions in the urban fabric are mitigated by underlying determinants of economic activity and social interactions (Nygard & Meen, 2013).

A central tenet of IRT is that positive transportation costs and nonlinear urban benefits can lead to multiple equilibria in spatial structures and growth trajectories. Which equilibria is established (Krugman, 1991b) and maintained is a function of history and expectations.

Under IRT, the impact of COVID-19 is *a priori* undetermined. A permanent change in the preferences for regional and peri-urban locations may alter the nature of urban amenities in city and inner-city locations that rely on density of jobs, people or income. In the absence of a short-run regional housing supply response, an expectation then is that the spatial patterns of house price appreciation does not revert to pre-COVID-19 patterns. Instead, property prices in regional and peri-urban locations will permanently alter relative to areas affected by the pandemic. Teleworking may reinforce these changes. For instance, under conventional space-access models, teleworking may reduce commuting costs, which in turn would incentivise relocating away from existing higher density residential areas. Government policies to stimulate regional development, including housing, might reinforce a decentralisation trend further. Similarly, longer-term

concerns around food production and security, disrupted supply chains, environmental concerns and heat stress may also incentivise greater numbers, particularly older Australians, to relocate rural and regional locations.

However, teleworking may also provide an impulse for mean reversion if preferences for regional locations are not permanently changed, but closeness to work becomes less important (thus increasing competition for locations closer to other urban amenities). Inner city locations have, over the past two-three decades, experienced an increase in employment and population (which might be negatively affected by teleworking) (Terrill, Batrouney et al., 2018). They have also experienced an increase in urban consumption and leisure amenities (shopping, restaurants and bars) and liveability. For instance, Melbourne and Sydney both regularly rank highly on the Economist Intelligence Unit's ranking of most liveable cities. A key consideration here is a tendency to activate rapid recovery responses to re-establish status quos and systems of governance in place prior to a shocks (Mykhnenko, 2016; Vale, 2014). In Australia, housing policies were used as economic management policies following the Great Financial Crisis and again in response to COVID-19 throughout 2020.

Finally, housing affordability may generate a centrifugal effect on location decisions. This affects both regional and capital cities. In the short-run, regional areas may experience an increased inflow of workers taking advantage of teleworking and COVID-19-related preference changes. However, regional markets are thin, compared to capital city markets, and thus require a significant supply response to remain affordable.

Overall, it is *a priori* difficult to ascertain how Australia's urban system will respond to COVID-19. As discussed under each of the three conceptual approaches (RGT, LFT, IRT), the impact of the pandemic will be a function of its interaction with the processes that shape Australian urban dynamics. In the following section, we therefore turn to three empirical tests that provide insight on the processes of urban dynamics in Australia, and their implication for assessing the impact of COVID-19. These processes are assessed in the long-term (1911–2016), medium-term (2002–2020), and short-term (2020).

3. Testing urban dynamics in Australia

3.1 Long-term growth patterns, 1911–2016

As discussed in the preceding Section, Zipf's Law describes a well-established empirical regularity for city size distribution. Data on population size for the largest Australian cities (upper end of the distribution) are available from 1911 to 2016 (ABS, 2019). The data include 42 and 49 cities and towns in 1911 and 2016, respectively. The Zipf coefficient is arrived at by regressing the log ranking of cities on the log of population. We follow Gabaix and

Ibragimov (2011) in obtaining unbiased OLS estimates of the regression slope by subtracting 0.5 from rank.

$$\ln(\text{Rank}_{i,t} - 0.5) = \alpha + \beta \ln \ln(\text{Size}_{i,t}) \quad (2)$$

In Eq (2), rank is the ranking of Australian city i at time t , according to $S_1 \geq \dots \geq S_{(n)}$, and S is size of city. We estimate the Zipf coefficient for each of the census years between 1911 and 2016. By tracking the Zipf coefficient for Australian cities over a 100-year period, we can track change in Australia's urban system over a period characterised by a series of potentially significant determinants of urban transitions. Some of these determinants include the lifting of the White Australia policy in the last 1960s (DIBP, 2017), economic restructuring from the 1970s, amenity-based internal migration since the 1970s (Bohnet & Pert, 2010), dominance of skills-based migration from the 1990s (Jupp, 2002) and large intake of temporary migrants since the 2000s (Boucher, 2016). Under RGT and LFT, a Zipf coefficient close to or exceeding -1 is expected, under IRT it can take a value of -1 .

Figure 1 below summarises the results of estimating Equation (2) for each census year over the period 1911–2016, and the share of Australians living in capital cities. The Zipf coefficient (β in Equation (2)) measures the extent to which the size distribution within urban hierarchy in Australia follows a power law distribution. A value closer to -1 indicates that the largest city is twice as large as the next largest, the third largest city is a third of the largest

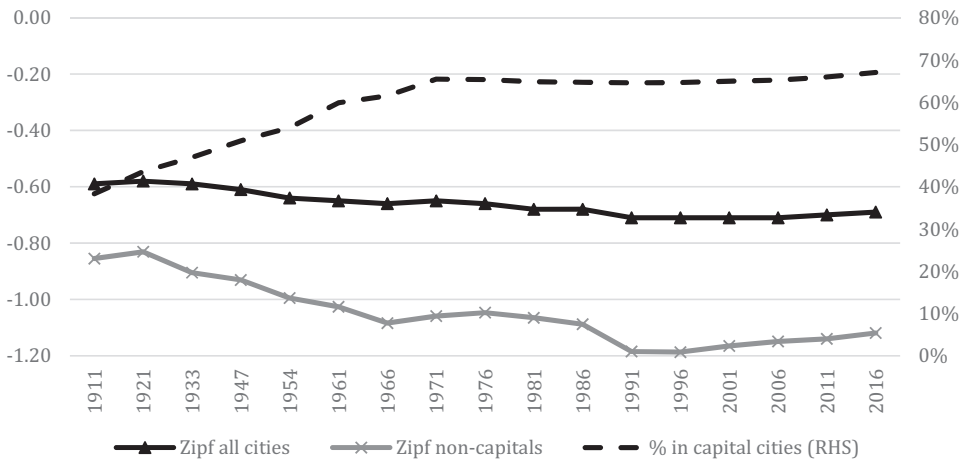


Figure 1 Zipf Coefficients and capital city population concentration, Australia 1911–2016. Note: Authors calculation from ABS (2019) Zipf all cities $r^2 > 0.90$; Zipf noncapitals $r^2 = 0.40$ – 0.78 . Number of cities in estimation ranges from 42 in 1911 to 49 in 2016. If estimating on a consistent set of cities ($n = 42$), the results remain unchanged. Combining Sydney and Melbourne changes the intercept by approximately -0.03 and -0.04 points in 1911 and 2016, respectively; combining all capital cities changes the intercept by -0.08 and -0.12 in 1911 and 2016, respectively. Noncapital cities excludes capital cities, but includes Canberra (results are indistinguishable when omitting Canberra).

city, and so on. A value of -1 is consistent with RGT, but can also be the case for LFT and IRT. The results in Figure 1 tell three stories.

First, throughout the period 1911–2016 the Zipf coefficient for all Australian cities is not equal to -1 . The standard errors for the ‘all cities’ estimates graphed in Figure 1 is 0.02. The size distribution of Australian cities is thus less conformant to Zipf’s Law and the power law distribution expected under the RGT. This is consistent with both recent and older international comparisons (Ellis & Andrews, 2001; Rosen & Resnick, 1980) and reflects Australia’s lack of mid-sized cities (Ellis & Andrews, 2001).

Second, the distribution of cities below capital city level (including Canberra) does, on the other hand, more closely conform to a power law distribution. The standard errors for the noncapital city estimates are wider (and the model fit somewhat poorer, see note to Figure 1). Urbanisation patterns in Australian noncapital cities thus behave differently from urbanisation patterns in capital cities. One interpretation is that increasing returns (e.g. agglomeration economies) and location advantage create and maintain primacy in the urbanisation patterns of capital cities (potentially also some regional centres), for instance by drawing populations from the regions and towns, and concentrating international migration.

In regional and smaller cities/towns, the g^{sec} component in Equation 1 may be more susceptible to temporary and permanent variations in economic conditions, resulting in greater variability in growth rates. Regional and smaller cities may also be susceptible to greater variation in growth rates arising from social changes (demographic, amenity migration) in interaction with local housing markets (supply constraints), resulting in a Zipf coefficient closer to -1 . A possible co-determinant of the rank-size distribution for smaller cities is teleworking practices. In 2000, some 20 per cent of employed persons regularly worked from home (ABS, 2001); by 2015, this had increased to nearly a third (ABS, 2016). The period 2000–2016 was also characterised by rapid house price appreciation in many capital cities. Housing affordability in major cities is, along with lifestyle, a frequently cited reason for relocating from urban to regional and peri-urban locations (CoreLogic, 2018; Costello, 2009; Marshall et al., 2003). The ability of smaller regional centres and towns to absorb this type of migration is, however, limited by local housing supply, again potentially contributing to variability in growth rates.

Third, over the period 1911–2016 there is some suggestion of the Zipf coefficient moving towards -1 for the ‘all cities’ estimates, but this appears to end in the early 1990s. Over this period, the urban system at the very top remained stable with Sydney and Melbourne ranked 1st and 2nd (unchanged over the period). Below this level, there is some churn (although the rank position of the capital cities *overall* is unchallenged and the share of Australians living in capital cities remained largely unchanged from the 1970s onwards). For the noncapital cities estimates, there is similarly a gradual increase in the Zipf coefficient, but the confidence intervals around these

estimates typically bring the Zipf coefficient close to -1 (for the period 1991–1996 it is around -1.1).

Examining Australian urbanisation patterns over the past century thus suggests that the growth dynamics of capital cities differs from those of smaller and regional cities, with the latter experience dynamics growth that may also reflect RGT.

3.2 Intra- and inter-regional migration, 2002-2020

Under conventional space-access models, centripetal and centrifugal forces jointly shaped locational decisions. For instance, agglomeration economies (such as higher wages and urban amenities) exert a pull on population, and congestion cost (such as housing affordability, but also communicable diseases or infection) exerts a push on population. A current focus of public debate is the potential exodus of households from capital cities (ABC, 2021), due to the effect of COVID-19 and teleworking opportunities, although the latter is also a ‘slow burn’ effect and noticeable prior to COVID-19.

With respect to the impact of COVID-19 on intra- and inter-regional migration flows, a key question is therefore whether these migration flows in Australia exhibit any long-run relationship with relative house prices. A long-run equilibrium relationship would be consistent with expectations under both LFT and IRT, but not RGT, *and* suggest that the effects of COVID-19 on regional relocation trends may subside over time. Notably, both migration and house price dynamics are more complex than reflected in a simple bivariate relationship and a fuller analysis will benefit from further post-COVID-19 data availability.

Intra- and inter-regional migration data and their relation to relative house prices allows us to track their co-movements since 2000. Unlike macro house price models, where migration (as a component of population change) is a determinant of property prices, the flow of migrants between regions (areas), or change in migrants, is often modelled as a function of relative property prices (Cameron et al., 2005; Meen & Nygaard, 2010). For Australia, research on urban to rural migration shows that a search for lifestyle outcomes and affordable housing underlies the motivation of (re)location decisions (CoreLogic, 2018; Costello, 2009; Marshall et al., 2003). Consequently, if demand for property and location is a function of where households want to live and work, and households at the margin evaluate the net effect of centripetal and centrifugal forces, then a relative change in property prices over time is expected generate a change in intra- and inter-regional household flows.

We test this proposition in an autoregressive distributed lag (ARDL) model, where the change in net internal migration is modelled as a function of the lagged levels of both house prices and net internal migration, as well as the lagged changes in both variables. The ARDL model thus provides insight on short and long-run relationships and allows for the testing of co-

integration (Pesaran et al., 2001). The general ARDL (1,1) specification (in error-correction representation) is:

$$\begin{aligned} \Delta IM_t = c_0 + c_1 t + \alpha(IM_{t-1} - \beta HPR_{t-1}) + \sum_{i=1}^{p-1} \varphi_{IMi} \Delta IM_{t-1} + \omega' \Delta HPR_t \\ + \sum_{i=1}^{q-1} \varphi'_{HPRi} \Delta HPR_{t-1} + u_t \end{aligned} \quad (3)$$

In (3), IM is net internal migration, measured as the sum of net intra- and inter-regional migration from Sydney, HPR is the ratio of house prices in Sydney relative to average house prices in Australia and u is an error term; φ and ω are vectors of short-run (change) coefficients; p and q are lag indices for IM and HPR, respectively; α is the speed of adjustment to long-run relationship and β is the long-run coefficient derived by normalising the lagged (level) HPR coefficient over the lagged (level) IM coefficient. Equation (2) therefore tests whether net internal migration from Sydney to other parts of NSW, plus other states, exhibits long-term re-balancing properties (co-integration) that might imply that adjustment to shocks, such as COVID-19, are likely to be temporary in nature. The existence of a co-integration relationship would provide some evidence for LFT and IRT, but not RGT.

Figure 2 illustrates the trend in relative house prices and trends in net intra- and inter-regional migration in Sydney over the period 2000–2020. Relative house prices are calculated as the Residential Property Price Index for Sydney divided over the Weighted Average Capital City Residential Property Price Index (ABS 6416.0). It is evident that over the entire period, Sydney is an exporter of households to the rest of NSW as well as other states. Notably though, the number of internal migrants correlates with the dynamics of the Sydney housing market in relation to dynamics of all other housing markets in Australia. When Sydney property price decreases relative to alternative locations in Australia, the number of internal migrants from Sydney declines vice versa. In addition, there appears to be a regular increase in net internal migration out of Sydney each December quarter. Broadly, over the period 2006–2016, Sydney property prices increased relative to alternative locations in Australia. Over this period, the number of intra- and inter-regional migrants increased towards the peak of the Sydney house price cycle (2017). With the easing of property price after 2017, the number of internal migrants from Sydney also declined.

In order to test whether there is a long-run relationship between net internal migration from Sydney and house price in Sydney relative to house prices in Australia, Tables 1 and 2 provide test statistics for the time series properties of the respective data series in Figure 2, and the output from estimating Equation (3).

Table 1 shows the Augmented Dickey-Fuller (ADF) test statistics (MacKinnon p -values) and the Hylleberg et al. (1990) test (HEGY) statistics for seasonal unit roots. The lag-length for the ADF statistic is based on AIC and SBIC statistics obtained from stata's varsoc command (not shown).

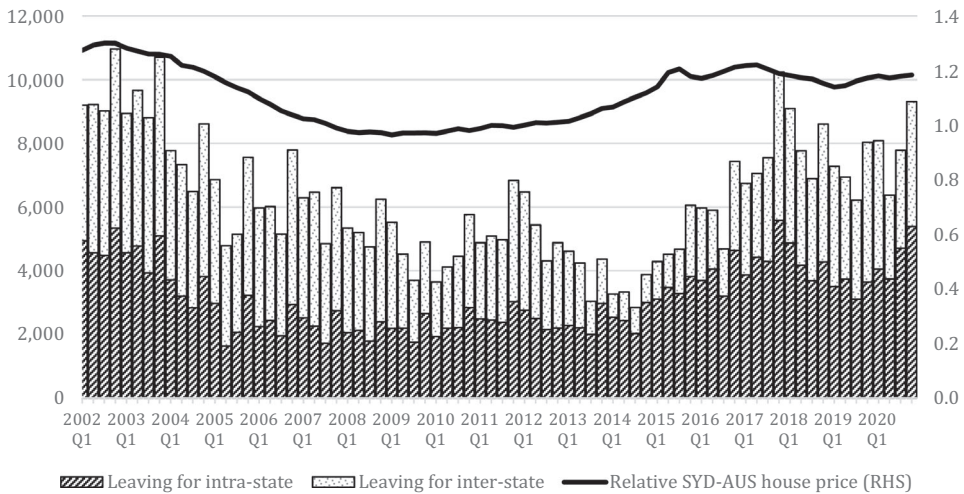


Figure 2 Net internal migration from Sydney and relative house prices, 2002–2020
 Note: Author’s calculations from ABS 6416.0 and ABS (2020a,b).

Table 1 Stationarity test internal migration and relative house prices

	Internal migration	Relative HP index
ADF Level, 5 lags	5 (0.073)	4 (0.222)
ADF First difference, 4 lags	4 (0.021)	3 (0.272)
ADF Level (drift), 5 lags	5 (0.043)	4 (0.017)
ADF First difference (drift), 4 lags	4 (0.001)	3 (0.023)
HEGY4 level $t(P_1)$, 5 lags	-1.826 (-3.015)	-2.146 (-3.020)
HEGY4 level $t(P_2)$, 5 lags	-3.702 (-2.990)	-7.230 (-2.994)
HEGY4 level $F(P_3 = P_4)$, 5 lags	36.181 (6.585)	16.573 (6.586)
HEGY4 First difference $t(P_1)$, 4 lags	-3.854 (-3.018)	-2.036 (-3.022)
HEGY4 First difference $t(P_2)$, 4 lags	-2.420 (-2.992)	-4.593 (-2.996)
HEGY4 First difference $F(P_3 = P_4)$, 4 lags	11.784 (6.586)	14.815 (6.587)

Note: ADF: p -values in brackets. For HEGY4 test t -value/ F -value compared to 5% critical value (in bracket). P_1 : one (nonseasonal) unit root at zero frequency, t -test; P_2 : seasonal unit root at semi-annual frequency, t -test; $P_3 = P_4$: seasonal unit root at annual frequency, F -test. HEGY test obtained using stata’s HEGY4 command.

The results in Table 1 suggest that both the levels of net internal migration (weakly so) from Sydney and Sydney house prices relative to all Australian house prices exhibit a unit root. When differencing the series, the null hypothesis (unit root) is rejected. Notably, when including a stochastic trend (drift) in the ADF test, a unit root can be rejected for either of the levels. There is, however, no deterministic trend (not shown). The HEGY test similarly suggests a nonseasonal root in both data series, but also the presence of a semi-annual and annual seasonal root in the levels. When first differencing, there is no longer a nonseasonal or semi-annual root in the internal migration series, but there is some evidence of an annual unit root. For the first difference of the relative house price series, there is some evidence

Table 2 Testing for long-run relationship between net internal migration and relative house prices

ARDL, lags (1,2)	Coefficient (standard error)
IM_{t-1} (α)	-0.294 (0.075)***
HPR_{t-1} (β)	11672.6 (3266.6)***
D1 HPR	12968.6 (8218.9)
LD HPR	-17768.7 (7995.8)**
Quartile 4	2131.6 (216.9)***
Constant	-2573.3 (1067.6)**
Adj r^2	0.708
N	68
Breusch-Pagan heteroscedasticity test	0.06
Breusch-Godfrey LM serial correlation test	0.009
ARDL Bounds test F -value	7.962***
ARDL Bounds test t -value	-3.896***

Note: Standard errors in brackets. */**/** is significant at 0.1/0.05/0.01 levels. ARDL bounds test is for long-run relationship between net internal migration and relative house prices (co-integration).

of both a semi-annual and annual unit root. The ADF test assumes that there is only one unit root in the data generating process. Here, seasonality in both the net internal migration and relative house price series therefore affects the time series properties of these two data series. A unit root in the levels may indicate co-integration (long-run relationship). Stationarity in the two difference series (and when including a stochastic trend) suggests mean reversion, such as might be generated under both LFT and IRT.

In Table 2, the results of estimating Equation (3) include a quarterly dummy (Q4) as an exogenous variable. Estimates are produced using Stata's `ardl` command (Kripfganz & Schneider, 2018). Optimal lag selection is based on the AIC statistic produced as part of the command.

The results in Table 2 provide some evidence that there is a long-run relationship between net regional migration from Sydney and house prices in Sydney relative to Australian house prices. β is positive and significant, suggesting that an increase in Sydney property prices relative to Australian property prices results in an increase in the number of households relocating away from Sydney. This might result from centripetal forces (such as relative housing costs) re-balancing once property prices rise in one location relative to another. For instance, higher capital city prices push households to regional locations, reducing demand and weakening price increases. In turn, higher demand in regional locations pushes up prices in regions, resulting in less available and more expensive housing that in turn chokes off new demand.

Although internal migration and relative Sydney house prices may deviate from their long-run relationship, the negative and significant α coefficient suggests that such divergence is temporary and largely balanced out within a year (four quarters). The bounds test confirms the co-integration of net internal migration and relative house prices in Sydney. There is no long-run relationship when Equation (3) is reversed (not shown).

Further research may explore whether there are long-run relationships between the residents leaving capital cities and the housing market dynamics of those cities, but for Sydney there is some evidence that shocks-induced outwards migration trends will dissipate over a relatively short period of time. Notably, this does not preclude longer-term trends or drifts such as might be associated with amenity-based migration or technology/teleworking changes. It does suggest, though, that these trends are not induced by temporary shocks themselves.

3.3 Spatial house price dynamics in Sydney in the initial COVID-19 period, 2020

Through 2020, the main lockdown period in Australia took place between March and June 2020. From June 2020 onwards, restrictions began to lift in all capital cities. The exception to this was Victoria and Melbourne where a second lockdown was in place from July to October 2020. Between October 2020 and June 2021, short-lived and spatially contained COVID-19 outbreaks occurred, but widespread lockdown conditions did not re-emerge until June 2021. At the time of writing (August 2021), both Sydney and Melbourne are in lockdowns. The June 2021 outbreak is not reflected in the data analysed in this paper.

Notwithstanding the easing of restrictions (apart from Victoria) in June 2020, housing markets remained disrupted by ongoing travel bans for international students and tourism with impacts on both short- and longer-stay rental and investment activity. The inner-city and high-density apartment market, more typically dominated by investors, has become increasingly segmented overtime catering for students and short-stay Airbnb tourists. Their exodus from CBDs has greatly impacted upon inner city rental prices (NHFIC, 2020a), with some renters relocating to these areas to take advantage of falling rents. Following the first lockdowns, falling investment demand in this segment was superseded with a surge of first homebuyers entering the market. Due to the ongoing contextual changes in the apartment markets our focus is primarily on the spatial dynamics of demand for houses – most typically occupied by owner occupiers – although we include analysis of units for completeness.

Under the RGT, areas experiencing a negative shock in demand due to COVID-19 should continue to see a decline in demand also after the shock period. Conversely, if areas that experience large declines during the initial shock are not associated with continued decline after the shock, then this provides evidence for mean reversion (e.g. reassertion of locational, employment or amenity benefits) – subject to other factors determining spatial patterns.

We follow the methodology detailed by Davis and Weinstein (2002) for testing urban dynamics following large exogenous shocks. Property prices are sourced from CoreLogic via the Australian Urban Research Infrastructure

Network (AURIN). CoreLogic provides the total value of sold properties for each month, and the total number of sales at Statistical Area Level 2 (SA2). We calculate average property prices (APP) for all SA2s with more than four sales. To account for seasonality, we calculate the relative property price (RPP) by dividing the SA2 level average property prices over the monthly average property price (for all SA2s in New South Wales) with more than four transactions ($RPP_{it} = APP_{it}/APP_{NSWt}$). Given the additional volatility that may arise from using average property prices (median prices are only available as 3-month averages), we winsorise the estimation sample, excluding the highest/lowest 1 per cent of relative change statistics during the initial 2020 lockdown period. We conduct tests for houses and units within 150 km of the Sydney CBD separately.

Formally, we have observations on relative property prices (RPP) at three time points in 2020 (t_1, t_2, t_3). The first time point is the average property price in March 2020, the second is June 2020, and the third is November 2020. June also coincides with a cut in the Reserve Bank of Australia's cash rate. We assume that the measurement of RPP for any SA2 at a given point in time is described by:

$$RPP_{it} = \Omega_i + \varepsilon_{it} \quad (4)$$

where Ω is an initial house price value and ε is an SA2-specific shock or deviation. The extent to which a shock to RPP persists can then be modelled as:

$$\varepsilon_{it+1} = \rho\varepsilon_{it} + \nu_{it}, \quad (5)$$

where ρ measure the degree of persistence in shock over time and ν is an independently and identically distributed error term.

We can analyse the evolution of the system of relative house prices by substituting (5) into the first differenced version of (4):

$$RPP_{it+1} - RPP_{it} = (\rho - 1)\nu_{it} + [\nu_{it+1} + \rho(1 - \rho)\varepsilon_{it-1}] \quad (6)$$

In (6), if $\rho = 1$ then shocks to the relative distribution of property prices are permanent. This would provide evidence for the RGT and suggests that the impact of COVID-19 persisted also beyond the initial pandemic period. However, if $\rho \in (0, 1)$, then shocks are temporary and disappear over time. In terms of relative house prices in Sydney, this would mean that areas that experienced large relative increases (decreases) due to the pandemic, subsequently experienced decreases (increases) in their relative value. The change in RPP between March and June 2020 provides an approximation of the COVID-19-related shock. However, this change may also contain information about pre-March 2020 growth rates and may thus be biased. For instance, in January 2020 the First Home Loan Deposit

Scheme (FHLDS) came into effect. The take-up of the FHLDS was particularly high in suburban and peri-urban parts of Sydney (NHFIC, 2020b). Additionally, following COVID-19 the HomeBuilder subsidy was introduced (June 2020), again directing demand to new build areas in outer parts of Sydney.

To address potential bias in the growth rate, we instrument the change in relative house prices (t_2-t_1) with the number COVID-19 cases in the local authority within which the SA2 is situated. Data and dates on COVID-19 cases are obtainable from the NSW Department of Health and Human Services. By instrumenting the COVID-19 shock, the estimation specification becomes:

$$RPP_{i,t3} - RPP_{i,t2} = \Phi [I(RPP_{i,t2} - RPP_{i,t1})] + \varepsilon_{i3}, \Phi = (\rho - 1) \quad (7)$$

In this specification ϕ (Φ) tests, a number of the above urban growth theories with respect to the persistence of temporary shocks. As noted, property market specific shocks took place before and after the 2020 COVID-19 lockdown. In controlling for these additional shocks, (7) is estimated with and without distance to the CBD.

Tables 3 and 4 show the results from estimating Equation (7) by IV approach. Equation (7) is concerned with testing the extent to which property market change during the immediate COVID-19 impact period, also persists beyond this period. The focus is here on the change in relative property prices as an indicator of impacts on spatial demand. Within a 150 km radius of the Sydney CBD, there is a negative association between the total number of COVID-19 cases and the change in house prices (t_2-t_1). Tests of the exclusion criteria meet both over and under identification test. With respect to units, there is not a significant relationship. Note, while the direction of the relationship holds for various radius settings, *statistical significance is sensitive to the distance setting*. Note also that the inclusion of distance to the CBD does not substantively change the coefficients on number of COVID-19 cases in Table 3.

Table 4 summarises OLS and IV results for Equation (7) for houses and units, respectively.¹ In column 2 and 4, no additional controls are included. The OLS results in column 2 suggest a limited degree of mean reversion following the immediate COVID-19 period. That is, areas where relative prices increased during the shock period often declined after the shock period. The IV results in column 4, however, suggest a random walk in this period ($\Phi = 0$), and so provide some support for ongoing COVID-19 related impacts and the RGT. In other words, the trend in RPP change during the March-

¹ We also estimated (5) using a spatial autoregressive (SAR) version of (5). The spatial lag and error (with an inverse distance spatial matrix) are both significant. However, the magnitude of Φ is unchanged from the OLS results.

Table 3 First stage regression: COVID-19 and change in property prices March-June 2020

	Houses	Houses (with distance)	Units
ln total C19 cases	-0.1844*** (0.0713)	-0.1983*** (0.008)	0.1862 (0.1595)
ln total C19 cases ²	0.0180* (0.0096)	0.0216** (0.0101)	-0.0251 (0.0196)
ln CBD (km)		0.0270** (0.0137)	0.0091 (0.0138)
Constant	0.4774*** (0.1317)	0.3786 *** (0.1397)	-0.3654 (0.3111)
SW <i>F</i> -test	10.03***	7.75***	1.24
KP under identification test, Chi ²	7.236**	6.208*	2.145
Hansen J statistic, <i>p</i> -value	0.634	0.448	0.770

Note: SW is Sanderson-Windmeijer multivariate *F* test of excluded instruments. KP is Kleibergen-Paap rk LM statistic). */**/***/*** is significant at 0.1/0.05/0.01. Estimates are clustered at LGA level. Standard errors in brackets.

Table 4 Sydney residential property market adjustment June-November 2020

	Houses			
	OLS	OLS (distance)	IV	IV (distance)
ln RPP change Mar20- Jun20 (<i>I</i>)	-0.3994*** (0.0911)	-0.5849 (0.1027)***	-0.0607 (0.2970)	-0.6741 (0.4130)*
ln CBD (kms)		0.1244 (0.0309)***		0.1328 (0.0334)***
Constant	-0.0888*** (0.0239)	-0.4520 (0.1218)***	-0.0920 (0.0261)	-0.4887 (0.1307)***
R^2	0.0418	0.193	0.012	0.179
SA2s (<i>N</i>)	283	283	278	278

Note: */**/***/*** is significant at 0.1/0.05/0.01. SAR results not shown. Estimates clustered at LGA level. Robust standard errors in brackets. ~ negative. \hat{R}^2 Centred R^2 for IV results.

June 2020 (first lockdown period) continued throughout June-November 2020.

As noted, the FHLDS and HomeBuilder policies both spurred demand in areas at a greater distance to the Sydney CBD. To proxy for the spatially non-neutral impact of these policies, we include distance to the CBD in the estimation of Equation (7). The first-stage regression results confirm that the number of COVID-19 cases remains a valid instrument also conditional upon the inclusion of distance to the CBD. When controlling for distance to the CBD, the difference between the OLS and IV results largely disappear. The coefficients for the instrumented COVID-19 shock suggests $-1 < \Phi < 0$ (although $\Phi = -1$ cannot be rejected, neither can a very low Φ), with the implication that the COVID-19-related impact on RPP substantially mean reverted.

The interpretation of the results in column 3 and 5 is that areas experiencing an increase in relative property prices during the shock, tended to experience lower increases in the immediate period after the shock – conditional on the distance to the CBD measure. The results in Table 4 leave a complex picture and perhaps also highlight that before and after COVID-19 tests remain premature at this stage. It is clear from the first-stage regressions in Table 3 that both COVID-19 and distance to CBD correlate with changes relative house prices during the shock period. The results in Table 4 suggests that the COVID-19-related effect substantially mean reverted following the shock, but around an outwards spreading trend. The partial mean reversion in turn provides evidence against the RGT theory and expectations that COVID-19, in the longer-run, will permanently alter our cities. Of particular interest for future research, then, is the outwards trend itself. The results in Table 2 suggest a likely rebalancing of demand and relocation patterns as housing markets in regions and capital cities adjust to their respective supply constraints. This does, however, not exclude the possibilities of increased suburbanisation of demand, as indicated by the distance to CBD coefficient in Table 4.

Further research is required to determine whether this partial mean reversion is indicative of path divergence (multiple equilibria), such as might arise if the opportunity and support to continue new working practices during COVID-19 differs across types of employees and employers, or an artefact of the limited time period under analysis. For those for whom teleworking is the future, the conventional price-distance model would suggest a flatter price gradient and housing locations at a further distance to centres of employment. This in turn might spur further amenity-based internal migration, although the results in Table 2 suggest that the strength of any such trend is also a function of Sydney house prices relative to house prices elsewhere.

4. Conclusion

In the period following the data examined in this paper, each of the state and territory capitals, with the exception of Hobart, has experienced, or is experiencing, new lockdown conditions. Whilst still grappling with the pandemic, it is thus premature to make strong predictions about specific impacts. Nevertheless, theoretical frameworks of urban growth and change following shocks combined with preliminary analysis can help guide a more proactive approach to shaping cities and delivering urban transitions to just, healthy and productive urban futures.

In this paper, long-term and short-term urban dynamics are analysed against random growth, locational fundamentals and increasing returns theories of urban growth and adjustment. In this context, the COVID-19 pandemic constitutes a shock to urban systems. This shock is, however, taking place against ongoing ‘slow burn’ urbanisation determinants such as the interplay between centripetal and centrifugal processes in capital cities,

and technology/teleworking and amenity-based migration for some household types.

For the Australian urban system as a whole and for intra- and inter-regional urban dynamics, our results suggest that the dynamics of urban developments and population relocations are characterised more by processes expected under LFT and IRT than random growth. There is, however, also some difference in the urban dynamics of capital cities and noncapital cities. In terms of COVID-19 impacts, this suggests that systemic impacts – the relationship between capital cities and regions as a whole – from COVID-19 may be transient. Overall, urbanisation trends appear predominantly determined by housing market dynamics in interaction with local economic determinants, endogenous and exogenous amenities, including labour markets.

This picture may, however, differ for micro geographies within cities, and for towns and regional centres, particularly those within commuting distance to capital cities. While micro geographies also respond to aggregate centripetal and centrifugal dynamics, they in addition respond to local dynamics that may be endogenous to income and socioeconomic concentrations, or local economic and planning (housing supply) conditions for towns and regional centres.

For such locations, the impact of COVID-19 may potentially be more substantial. Teleworking practices, for instance, alter the relationship between the income elasticity of housing demand and marginal valuation of commuting time. For some types of households (workers), this suggests a flatter gradient and demand for properties at further distance to the CBD. Our results suggest a change in the relative distribution of property prices during 2020 within Sydney. However, the component attributable to COVID-19 appears to also exhibit a degree of mean reversion, again inconsistent with RGT or the ‘cities will change as a result of COVID-19’ argument. Nevertheless, the impact of COVID-19 comes on top of underlying dynamics and policy innovations that also incentivise relocation towards suburban, peri-urban and regional centres within commutable distance to capital city employment centres.

A particular insight from examining the urbanisation dynamics in the short, medium and long term is thus that it is likely the policy response and its interaction with underlying fundamental housing, economic and social processes that will shape the trajectories of our cities. COVID-19 may serve as a ‘justification’ for particular policy decisions, but the disruptive effect of COVID-19 is more likely an outcome of policy and fundamental processes, than COVID-19-induced change.

A key consideration for policymakers and city planners will thus be the extent to which they facilitate housing market responses (supply) that either accommodates increased demand for peripheral locations, or whether a lack of supply eventually chokes off the increase in demand. For many cities this might also imply re-visiting current ‘compact city’ models, the role of regional centres as housing and employment hubs, and pathways to sustainable urban futures.

Data availability statement

Most of the data that support the findings of this study are available from the Australian Bureau of Statistics at www.abs.gov.au. These data were derived from the following resources available in the public domain:

Regional internal migration estimates, provisional, December 2020, www.abs.gov.au

Residential property price indexes: eight capital cities, Cat.No. 6416.0, www.abs.gov.au

Historical population, Cat.No. 3105.0. www.abs.gov.au

The NSW COVID-19 incidence data that support the findings of this study are available from the corresponding author upon reasonable request. These data were downloaded from the NSW Department of Health website on 4 January 2021.

The property data that support the findings of this study are available from the Australian Urban Research Infrastructure Network (AURIN). Restrictions apply to the availability of these data, which were used under license for this study. Data are available on www.aurin.org.au.

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