The Occupational Dimensions of Local Labour Markets in Australian Cities

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It has been argued that declining housing affordability in Australia's major cities has led to the exclusion of many low- and moderate-income residents from high-employment, inner-city regions. If there is an increasing spatial mismatch between housing and employment, moderately paid workers, essential to the efficient functioning of the urban economy, may face problems in accessing and retaining employment. However to date there has been a lack of empirical analysis of the spatial dimensions of housing and employment (and the commuting such divisions necessitate) broken down by occupation. Using the aggregate 2001 Census Journey to Work data by Statistical Local Area (SLA), we apply a spatial aggregation algorithm to develop largely self-contained commuting areas in Sydney, Melbourne and Brisbane. We establish that these areas are also relatively self-contained with respect to commuting flows by occupation. We employ linear programming techniques to determine the spatial patterns of commuting by occupation within these metropolitan commuting areas which minimize the corresponding average distances commuted. The results reveal some variation in commuting patterns across occupations but little evidence of longer commutes for the low-skilled. The results highlight the need to separate out the 'volitional' or 'excess' component from the overall commute, particularly if relying on commuting data to make inferences about how considerations of housing affordability impact on the locational decisions of lower-income workers within metropolitan areas.

A wide range of factors, including housing affordability, proximity to work and amenities, as well as childcare, schools, recreational facilities and shopping, and access to the extended family and friends, impact on the interdependent decisions made by members of households about employment and housing location. The availability of both private and public forms of transportation influence the potential distance commuted, with the former in turn being linked to the availability of sufficient household income, and hence job opportunities, particularly in the light of rising petrol costs.

Berry (2006) points to the intensification of the spatial polarization of housing and employment which is associated with declining housing affordability within Australia's major cities, in particular Sydney. In turn it has been argued, both here and overseas, that growing inner-city skill shortages reflect the way house price appreciation has worked to exclude low- and moderate-income residents from high-employment, inner-city regions (see DEST, 2002; Nelson, 2004). Low- and moderate-income workers who are forced to live where housing is affordable (in the outer suburbs) undertake longer commutes. This acts as a deterrent to employment, and imposes costs on employers in the form of higher staff turnover, lengthy recruitment periods to find replacement staff,

and extra costs associated with training staff (Yates, 2005). Berry (2006, p. iii) argues:

> in effect, urban housing and labour markets may be inefficiently articulated over space with consequences of shortages and recruitment difficulties in some lower paid but functionally necessary occupations and/or higher wages to offset high housing costs or more expensive commuting. In the latter context, a series of negative second-order externality effects may arise due to the sharp rise in car dependent commuting.

In short, are housing markets pricing low- and moderate-income workers out of job-rich areas and promoting economic inefficiency?

Our analysis involves an examination of broader occupational differences in commuting, because the available data do not allow us to isolate those public sector employees who are identified in the key worker hypothesis. We build on previous approaches through the adoption of a coherent methodology for the formal analysis of commuting patterns within metropolitan areas of Sydney, Melbourne and Brisbane. We first construct Commuting Areas[1] (CAs) – that is we adopt a formal approach to defining metropolitan labour markets in a statistical sense, based on self-containment with respect to where most workers live and work. We compute average commuting distances and self-containment rates for one- and two-digit ASCO occupations.

We then explore the nature of commuting by occupation in Sydney, Melbourne and Brisbane, by drawing on Charron's conceptual distinction (2007) between the 'morphological' and 'behavioural' components of commuting for one-digit occupations in light of the finding that changes in the housing market may be placing stress on the journey to work. Preliminary analysis of average commutes and self-containment ratios reveal little variation across occupations but higher self-containment ratios are revealed at the SLA level for low-skill occupations. Overall this evidence lends support to Yates (2005) and Yates *et al*. (2006) who find little evidence that low-skill occupations have lower levels of employment accessibility. We then introduce the notion of the minimum commute for each occupation in each CA. High levels of minimum average commutes across low-skill occupations would be consistent with the constraints of housing affordability, causing low-skill jobs to be relatively more dispersed than the distribution of residents, in contrast to higher-skilled occupations.

We can then compute the extent of excess commuting by occupation and CA which represents the 'volitional' component of commuting. High-skill occupations tend to display higher rates of excess commuting, reflecting that factors other than job proximity may influence their location decisions.

We find that, while the higher-skill occupations tend to have a higher volitional component to their commuting patterns, low-skilled occupations do not have a systematically higher minimum commute, which would be consistent with housing affordability constraining residential choices.

The next section reviews the current literature, and this is followed by sections which outline data and methodology, report results and conclusions.

Literature Review

Sassen (1991) and other urban theorists argue that the presence of growing concentrations of advanced business services and other knowledge-intensive jobs in large urban centres separate global cities from non-global cities 'with respect to size, function, influence and prosperity' (Berry, 2006, p.7). Likewise theories of spatial polarization (and the Divided City Hypothesis, see Fainstein *et al*., 1992) argue that new economy processes have driven occupational polarization and created pervasive patterns of spatial differentiation within cities. Not only is demand for high-skill and high-wage employment increasing, but demand for low-skill, low-wage workers is also increasing. Earlier work by Baum (1997) documents these patterns within Sydney and shows that shifts in the occupational

structure of cities have resulted in the growth in employment of high-paid professionals and low-paid service workers. A third group is also identified, namely persons without access to paid work. Baum (1997, p. 1900) states that:

> at one end of the scale there exists a growing group of high-income, high-status individuals who are strongly attached to the global economy and have benefited from global integration. At the other end, there is both a growing group of workers who have only weak labour market attachment to the global economy (low-paid service workers) and a group of workers who are outside the employed labour force, are dependent on welfare, and have benefited very little from global processes.

These low-paid service workers serve an ancillary function and complement new economy/professional workers within urban centres.

There is some overlap between the key worker hypothesis and the longstanding theoretical and empirical debates relating to spatial mismatch. Spatial mismatch can be concisely defined as frictional unemployment resulting from the lack of spatial congruence between a worker's place of residence and her/his potential place of employment. However mismatch, which in part reflects urban form in the sense of the spatial pattern of housing and employment, may also be manifest in higher wages or excess commuting, or both, rather than unemployment. Gobillon *et al*. (2003, p. 21) provide several reasons why housing markets, via increased distance to place of employment, might impact on labour market outcomes. For instance, workers living far away from jobs face reduced access to and quality of job information and employers favour locally-based recruiting methods. Second, financial incentives are insufficient to motivate distant workers to search, because search costs are not compensated by wages. Also differentials in dwelling rents are too great to encourage relocation. Third, commuting costs (associated with length of commute) are also not compensated by wages. Fourth, employers do not perceive a worker who lives in a distant location from the workplace as a direct substitute for a worker who lives close to work. Lastly, inadequate public transport may exacerbate these issues.

While the impact of spatial polarization of housing prices has typically been viewed as an equity issue, the key worker hypothesis emphasizes that the decline in housing affordability has a potential impact on economic efficiency through the generation of both skill shortages and unemployment (or employment unrelated to a person's previous occupation, skills or training). As Berry (2006) notes, there has been little research into the spatial mismatch debate in Australia and what has been done is largely anecdotal, but there is some empirical work refuting spatial mismatch in Melbourne (Dodson, 2005). The paucity of hard evidence is mainly the product of the scarcity of relevant spatial data at an appropriate level of disaggregation.

The claim that low-income or moderate-income workers have had difficulty accessing employment in the city, owing to housing constraints and long commutes, has gained increasing traction overseas. In the UK the focus has been on specific public sector occupations, especially in areas with high and rising housing costs which have had implications for 'recruiting and retaining' teachers, nurses, police and emergency service workers, municipal officers and health care workers. The UK government has referred to these workers as 'key workers'. In London, affordable housing policies have been introduced which require '50 per cent of all new housing developments to be affordable' (Yates, 2005, p. 19). In the US similar concerns have been raised, with recent research carried out by the Essential Worker Immigration Coalition, Urban Land Institute and National Housing Conference pointing to a shortage of appropriate housing for low- and moderate-income workers in many large cities (Berry, 2006, p. iv). In a number of US States, 15 to 25 per cent of all housing developments are required to be affordable (Yates, 2005, p. 19).

In Australia, a NSW Department of Housing report defined key workers as 'workers who provide a service that contributes to the well being of the community and are unable to afford appropriate accommodation on the open market. The definition includes, but is not limited to, hospital workers, teachers, child care workers, police, transport workers or fire fighters' (Yates, 2005, p. 7).

Australian regions typically display high levels of self-containment – that is, most people live and work in the same region – although over the last two decades residential and commercial gentrification has intensified, pushing low-income workers to the fringes of the city (Berry, 2006; Dodson *et al*., 2006). The decentralization of value-adding jobs has not occurred in the Australian labour market as it has in many cities in the US (Berry, 2006, p. 7). Yates *et al*. (2006) find high rates of housing stress amongst lower-income working households, with hospitality workers experiencing the highest incidence of housing stress and sales assistants recording the greatest numbers in housing stress. However, public sector occupations such as police or teachers, which are central to most conceptualizations of the key worker hypothesis, face a below average incidence of affordability problems (Yates *et al*., 2006, p. vii). Housing affordability problems are not driven by occupation *per se* but by low incomes (reflecting underlying wage inequality across occupations) and locational choices. The highest incidence of housing stress is found amongst workers in the Sydney metropolitan region, in south-eastern Queensland and in inner regions of Melbourne (Yates *et al,* 2006, p. vii).

In some of the only occupational analysis of the journey to work undertaken to date, Yates (2005) and Yates *et al*. (2006) examine commuting patterns which reveal that only some occupations (namely computing professionals) had an increased proportion of workers facing long commutes, because they chose to live further out and their work was more likely to be located in inner-city locations. They find that there are high levels of self-containment at a broad regional level within these key metropolitan regions, with approximately half of the workforce living locally (Yates *et al*., 2006, p. ix). Between 1996 and 2001, most workers had reduced their incidence of commuting beyond their own statistical subdivision (SSD), of which there are fourteen in the Sydney major statistical region. Earlier Yates (2005, p. 17) also found only limited support for the notion that, in Sydney, structural change had resulted in re-urbanization via an increased reliance on new economy jobs in the inner city. She found that, with the exception of computing professionals:

> there has been much greater growth in jobs in the locations where an increasing proportion of workers are living. In the case of Sydney, this is in the fringe regions of the city. The results for Sydney lend support to O'Connor and Healy's [2002] claims that 'jobs do follow people although care does need to be taken in drawing the implications about the direction of causality between growth in workplace and residential locations of workers'.

However Yates *et al*. (2006) restrict their analysis to four key occupations referred to as 'indicator' occupations: computing professionals, nursing professionals, hospitality workers and cleaners (based on the DEWR National and State Skill Shortage Lists). Overall the authors find that those who work in these high-cost, job-rich, inner-city regions tend to commute from nearby regions; and secondly the inner-city areas themselves have attracted increasing proportions of the local workforce to live there, especially nurses and computing professionals. Yates *et al*. (2006, p. x) conclude that 'there is little direct evidence to support the claims of those who express concerns that employers in high-cost areas such as the inner city cannot attract key workers because of housing affordability problems'. Housing affordability issues are likely to be greater for private sector workers in hospitality than public sector workers like teachers, nurses and police officers (Yates *et*

al., 2006). Moreover occupational factors in general may be less significant in explaining where people locate than socio-demographic factors, with young mobile workers occupying inner-city accommodation and providing an itinerant workforce for those low-wage service sectors.

However, even if not directly related to labour market shortages, worsening housing affordability may be generating a range of problems associated with poorer employment accessibility and longer commutes and the impacts may be different for different occupations. As Yates (2005, p. 10) notes:

> the final and most difficult conceptual issue [arises] from the inherent difficulty in determining the impact of housing costs on labour market shortages. This cannot be determined solely from affordability measures because lower-income workers who work in high-cost areas might simply undertake longer commutes from areas where housing is more affordable. Consequently, the analysis of their housing cost or affordability position *per se* may show relatively little to be concerned about. The downside however is increasing commuting costs, social stress and poor traffic and environmental outcomes, rather than labour market shortages.

Flood and Barbato (2005, p. vii) argue that commuting has three negative impacts on people's lives by impacting on (*a*) their psychological and emotional well-being; (*b*) their relationships and interaction with their families, neighbourhoods, communities and workplaces; and (*c*) their physical and social environment.

Recently, Dodson and Sipe (2006) have shown that rising petrol prices may be impacting severely on those with poor employment and service accessibility in the outer suburbs and city fringe. For low-income households the increasing cost of longer commutes, associated with higher petrol prices, is likely to impact further on already constrained household budgets. Examining data from the 2002 wave of the Survey of Household Income and Labour Dynamics Australia (HILDA), Flood and Barbato (2005) conclude that the two occupational groups with the longest commuting times to and from work are tradespeople, and managers/administrators. People in Sydney faced the longest average commuting times of employees in the country, of four hours and forty-three minutes per week (Flood and Barbato, 2005, p. 12). As Pocock and Masterman-Smith (2006, p. 7) note, 'issues of commuting are very important to household welfare', and a dual earner household in Sydney lost nine and a half hours per week to commuting in 2002 (Flood and Barbato, 2005). Moreover, as Flood and Barbato, (2005, p. 29) indicate, one in five men working full-time with children under 15 years spent more time commuting than they did with their children in 2002. Also, longer commuting times were associated with less time being spent socializing with family and friends and participating in sports and community groups.

While such trends are worrying, is job-proximity the central issue in long and burdensome commuting times? Given that a wide range of factors influence residential location relative to work,[2] we examine occupational variations in commuting and ask what component of commuting by occupation is necessitated by the corresponding spatial distribution of employment and resident location and what component of commuting might be considered volitional or related to factors other than simple job proximity?

Data and Methodology

We have obtained a custom release of Journey to Work data taken from the 2001 Australian Bureau of Statistics (ABS) Census of Population and Housing for the whole of Australia by one digit occupation. In addition, counts of commuters by two-digit ASCO occupations for destination and origin Statistical Local Areas (SLAs) within NSW, Queensland and Victoria were obtained. Cross border commutes were also provided for Queensland and NSW and for Victoria and NSW. The coding of work

destination zones is based on the address of the person's usual workplace. Destination zones are designed by State and territory based transport authorities and are devised to analyse planning and urban transport patterns and systems (ABS, 2002). Destination Zones aggregate to Statistical Local Area (SLAs), the spatial unit used in this analysis.

Our distance calculations use the Euclidean distance between the centroids of the SLA origin and destination, which captures distance as 'the crow flies'. These calculations are unlikely to give an accurate measure of actual distances commuted within Australian cities, given that road networks, time of travel (related to congestion) and mode of transport may cause significant variation in distance travelled. However Charron (2007, p. 8) defends the use of Euclidean distance as the correct metric on technical and theoretical grounds, despite these shortcomings. The dynamic nature of the metropolitan system is alleged to proscribe the use of time. Recorded travel times reflect the efficiency of the transportation system and, in particular, its capacity to counter congestion. Charron claims that Euclidean distance is a static, theoretically neutral measure of distance. Also he notes that collection of these data is not reliant on a costly network analysis. We adopt the usual practice for the measurement of intra-SLA commuting distance. The associated SLA is assumed to be circular so that the mean commute is given by the corresponding radius (Horner and Murray, 2002).

The research proceeds in two steps. First we use a technique developed by Coombes and Openshaw (1986) to identify so-called Commuting Areas via the grouping of areas, based on high rates of self-containment with respect to commuting flows. Second, we solve the Transportation Problem to compute a number of summary measures of commutes by occupation. We outline these techniques below and then explore their conceptual and empirical relevance to the study.

Commuting Areas

Any discussion of the constraints workers may face in accessing employment necessitates some understanding of the local labour market. While the ABS disseminates its Labour Force Survey (LFS) using labour force regions, these are largely based on labour force size with some reference to population homogeneity (ABS, 2004). If these areas do not in fact represent inherently meaningful units in an economic sense (i.e. conform to theoretical notions of local labour markets), the interpretation of these data is compromised, due to the presence of the Modifiable Areal Unit Problem (MAUP). The MAUP is present in all spatially aggregated data, and involves scale (the size of groupings) and aggregation or zoning effects (the particular way units are grouped). The implications of the MAUP are that the results are not necessarily independent of the units being used, and researchers need to be cautious in considering whether the unit is meaningful or appropriate to the question being asked and whether results may vary across units, and if so why. In the policy context, if a labour force area is defined too narrowly in a spatial sense, labour market policy implemented by one local administration can impact on a larger economic area which incorporates other administrative areas (Andersen, 2002, p. 834). Alternatively, if labour market policy is spatially localized in its impact, policy also needs to be implemented by adjoining local administrations. For the purposes of this analysis we use the term 'commuting area' rather than 'local labour market'.

Coombes (2002, p. 1503) identifies three approaches to the creation of local labour markets through spatial groupings, namely clustering, hierarchical, and rules-based, but there are others, including boundary analysis. Cluster analysis progresses from the initial set of areas to the final set of regions in one step, drawing on the relative similarity of the statistical properties of the areas, as measured

by an affinity matrix. Coombes also points out that clustering approaches usually specify the required number of regions at the outset, but that such an approach cannot ensure that all regions will meet the minimum statistical objectives. This constraint, plus the requirement of contiguity, reduces the options that are available, so the resulting grouping is likely to be sub-optimal.

One form of spatial aggregation, which has been used to overcome the deficiencies of administratively defined areas, is based on the concept of Travel to Work Areas (TTWAs). UK researchers define a TTWA as a geographical area within which a high percentage of commuting by residents occurs. It is the site for the interplay between labour supply and demand and, in principle, should be the appropriate area over which labour market statistics can be defined (Coombes, 2002, p. 1). These spatial markets result from both costs of mobility between jobs and the limitations of information networks. Employers and workers within a TTWA are assumed to be well informed and able to respond quickly to changes in market conditions. So each TTWA is considered to be largely self-contained (closed) from the rest of the economy, even though some commuting flows do cross boundaries.

Using measures of closure and interaction based on commuting patterns, Coombes and Openshaw (1986) developed an algorithm to identify TTWAs based on UK Census data. Watts (2004) discusses the algorithm in some detail but, in summary, base spatial units are initially constructed (usually in the most disaggregated form at which the spatial data are available). Second, the researcher identifies spatial units with high levels of self-containment, in terms of job-ratio and supply-side self-containment. Third, foci that display high interaction/inadequate self-containment are amalgamated. Fourth, these early 'commuting areas' (CAs) are expanded by grouping with other foci and non-foci with which they have high levels of interaction. Then remaining residual non-focus SLAs are allocated to the CAs. Based on a minimum self-containment, CAs are then iteratively dismembered and reallocated to corresponding CAs until all areas are absorbed (Watts, 2004, p. 467).

The algorithm has been adopted with some amendments in a number of recent international studies, including Spain (Casado-Diaz, 2000), New Zealand (Papps and Newell, 2002), Denmark (Andersen, 2002), USA (Tolbert and Sizer, 1996), in addition to Britain (Coombes *et al*., 1997), and also New South Wales (Watts, 2004). Across this literature different terminology has been employed to identify these areas. For example, Andersen (2002) uses the term Commuting Area, whereas Casado-Diaz (2000) refers to Local Labour Market Areas, Papps and Newell (2002) identify Functional Labour Market Areas and Tolbert and Sizer (1996) determine Commuting Zones. As indicated above, we adopt the term Commuting Areas (CAs)[3] which adequately identifies the source of the grouping of areas and is agnostic about its economic significance. Work by Watts (2004) has applied this technique to examine local labour markets in Australia using 2001 data. His findings indicated that the spatial classification employed by the ABS did not accord with commuting patterns developed, while the Bureau of Transport and Rural Economics classification (BTRE, 2003) appeared to provide a reasonable match.

The Transportation Problem and Excess Commutes

The key worker hypothesis and, more generally, the spatial mismatch hypothesis argue that the spatial distribution of housing and jobs is more polarized for some key public sector occupations and/or certain demographic/social groups. That is, the urban form, defined here as the overall distribution of housing and jobs, is not as favourable for certain occupational groups. These hypotheses are not simple to explore, however, because of the difficulty in separating

the discretionary component of commuting from constraints on patterns of commuting arising from housing affordability. Charron (2007, p. 2) argues that commuting consists of a morphological and a behavioural component. The morphological component is associated with urban form – that is the underlying spatial imbalance between housing and jobs. By definition, this component forces workers to commute.

The early research on commuting behaviour assumed a monocentric urban area, but the pattern of commuting was inconsistent with this underlying premise, since high rates of excess commuting were found (Hamilton, 1982). White (1988) dropped the assumption of monocentricity and took explicit account of the spatial location of workers and jobs. She developed a linear programming problem to determine the pattern of commuting flows across areas within a conurbation which yielded the system wide minimum average commuting costs (based on distance, time or both reflecting the total direct and indirect costs of commuting), given the spatial distribution of workers and jobs (see also Giuliano and Small, 1993; Horner and Murray, 2002; and Horner 2002). White (1988) found little excess commuting. Using a fine disaggregation of origin and destination zones, Giuliano and Small (1993) found the rate of excess in-commuting for five county Los Angeles regions to be about two-thirds, which challenged the minimization model. However commuting patterns are likely to reflect variations in household characteristics, preferences and local amenities, as well as housing costs (Giuliano and Small, 1993).

The so called Transportation Problem (TP) can be specified as the choice of a Journey to Work (JTW) matrix $[y_{ij}]$, where y_{ij} denotes the number of trips between residential location i and job location j, which minimizes the overall cost of commuting, subject to the solution satisfying the row sum (resident employees) and column sum (local employment) constraints imposed by the actual JTW matrix, $[x_{ij}]$, I = 1, 2,…n; j = 1, 2,…n, where n denotes the number of employment and residential locations. In this paper the objective function to be minimized is the total distance commuted, D where

$$D = \sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij} y_{ij} \quad (1)$$

which is equivalent to minimizing the average commute since the number of commuters is fixed.

Denoting actual distance commuted as D_a, with a corresponding minimum value of D_r, then the rate of excess commuting, Z is defined as:

$$Z = (D_a - D_r / D_a) \quad (2)$$

Thus the Transportation Problem can be defined as the solution to the hypothetical question of where workers in a particular occupation ought to live such that the system-wide commute (i.e. (average) distance commuted by all persons in that occupation) is minimized, taking the overall spatial patterns of employment and available housing for each occupational group as given by the column and row sums of the actual JTW matrix for that occupation. The minimum commute can be identified with the 'urban form', because workers could not live any closer to jobs in their field without lengthening commutes for others in that occupation. Thus, by hypothetically placing workers in the closest residential location to the jobs in their field, we can shed light on those occupations facing greater spatial constraints – that is longer commutes – given the underlying 'urban form' or job-proximity.

Comparison of the actual commute and the new hypothetical minimum commute for each occupation yields measures of 'excess commuting' – that is how far workers are living away from what would be optimum if each occupational group collectively decided to minimize its average workplace commute.

The TP can be recast by assuming that the residential locations of workers are given,

and that workers in each occupational group collectively choose their locations of employment to minimize the average commute, subject to the constraint imposed by the column (employment) sums of the corresponding JTW matrix.

Most empirical studies of (excess) urban commuting treat workers as a homogeneous group, so that a single TP is solved for each Commuting Area (see, for example, Horner, 2002). Thus, depending on how the TP is specified, all workers are assumed either to be able to work in all jobs or to be unconstrained by considerations of housing affordability in their residential choices. In addition, unless land markets operate in a manner consistent with the location model, commuting cost minimization would not yield the same pattern of commuting (Chen, 2000, p. 164). For instance, the model also assumes that the housing market clears simultaneously, which in practice it does not.

Thus any interpretation of solutions to the Transportation Problem must be highly qualified. We have addressed worker heterogeneity by differentiating on the basis of occupation, but acknowledge that workers' skills are not homogeneous within each one-digit occupation, and equally that the presence of inter-occupational wage inequality means that workers in a given occupational group do not have equal access to housing.

In the TP the urban form is treated as exogenous, notwithstanding the fact that it is confined to the residential locations of the employed (and their work locations), which is the aggregate outcome of residential decisions made by the employed and those not working which necessarily have a discretionary component. Hence, while acknowledging that the urban form as represented by the spatial distribution of housing and jobs cannot be strictly viewed as exogenous, we argue that exploring the cross-sectional variation of the minimum commute by occupation reduces part of the discretionary component of commuting behaviour and provides some insight as to whether workers in certain occupations are being required to commute further, due to problems of housing affordability. In addition, to treat the spatial distribution of housing and jobs of, for example, professionals as in some sense exogenous to professional workers is problematic, since it too is the outcome of thousands of interdependent decisions made by the employed (across all occupations) and the non-employed.

Within this excess commuting framework, the optimal commute (across a relatively self-contained area) is represented by the minimum commute solution to the TP. Thus Charron (2007, p. 2) argues that the difference between the actual commute and the minimum commute represents the behavioural component of commuting and reflects individual characteristics. Workers are prepared to tolerate the inconvenience of (additional) commuting in order to benefit from indirect rewards, which are primarily a broader range of residential and employment choices, but also can include better access to amenities and relatives and friends.

Horner (2002) argues that the measure of excess commuting needs to be put in perspective by the computation of a maximum average commute which is obtained by respecifying the TP as a maximizing, rather than a minimizing, problem. A region may have a relatively high rate of excess commuting, as represented by (2), but the relative rate of excess commuting may be relatively low, as measured by $(D_a - D_r) / (D_m - D_r)$, where D_m denotes the maximum commute. The maximization and minimization solutions form the limits of 'commuting capacity' supported by the urban form (Charron, 2007, p. 4).

Yang (2005) uses an alternative pattern of commuting as a benchmark for the actual commute, namely Proportionately Matched Commuting (PMC). It is based on the premise that all workers compete equally for all jobs within the self-contained area, irrespective of the distance between residence and work, so commuting is essentially random. The

expected number of workers who commute from zone i to zone j is given by

$$z_{ij} = \bar{x}_i \, \bar{x}_j / W \quad (3)$$

where W denotes total commutes (employment) and $\bar{x}_i$, $\bar{x}_j$ respectively denote the total number of residents in location i who are employed and total employment in location j. The resulting JTW matrix $[z_{ij}]$ satisfies the column and row constraints. We also compute the ratio of the average distance commuted to the expected distance commuted based on PMC. A high value of this ratio would suggest that factors other than commuting distance are influencing the residential location decision, since it appears that commuting distance is not being minimized.

Results

We adopt the following analytic techniques in this paper. First, the Coombes algorithm is applied across 1317 Australian SLAs based on aggregate commuting data for which the occupation of employment is known. The objective is to identify a single common, geographical area in each State capital which has a high rate of self-containment with respect to aggregate commuting flows, thereby avoiding significant error arising from ignoring flows out of and into each CA. This will enable a meaningful comparison of commuting patterns by occupation.

The algorithm yields 79 CAs across the country, when parameters to achieve a high rate of self-containment are used. The urban CAs corresponding to Sydney, Melbourne and Brisbane consisted of 52, 92 and 235 SLAs respectively. They exhibit high rates of overall self-containment by residence and employment with respect to total employment (Sydney: 0.990 and 0.989; Melbourne: 0.991 and 0.986; and Brisbane: 0.965 and 0.964). Using these CAs based on aggregate commuting data, we calculated closure rates by residents and employment across the nine ASCO2 occupations, to check that there was minimal leakage of commutes out of and also into the CAs, which would prejudice any comparisons of the summary commuting statistics (table 1). The minimum rates of closure are for Employment 0.944 (Managers, Brisbane) and for residents, 0.951 (Tradespersons, Brisbane), which are somewhat lower than for Sydney and Melbourne, but are still of an appropriate magnitude.

We calculate a range of summary statistics for each occupation in table 2 namely the actual, proportionately matched, minimum and maximum commutes for each major occupation and in total, with the last two summary statistics being the solutions to the

Table 1. Closure rates by occupation for urban commuting areas.

	Sydney		*Melbourne*		*Brisbane*	
	Res	*Emp*	*Res*	*Emp*	*Res*	*Emp*
Total	0.990	0.989	0.991	0.986	0.965	0.964
Managers	0.989	0.989	0.988	0.983	0.961	0.944
Professionals	0.991	0.988	0.990	0.986	0.970	0.967
Assoc. Professionals	0.989	0.989	0.991	0.984	0.967	0.961
Tradespersons	0.986	0.986	0.990	0.982	0.951	0.954
Advanced Clerical, Sales and Service	0.994	0.993	0.995	0.990	0.979	0.967
Intermediate Clerical, Sales & Service	0.991	0.990	0.993	0.987	0.973	0.970
Intermediate Production and Transport	0.987	0.987	0.991	0.983	0.953	0.959
Elementary Clerical, Sales and Service	0.991	0.991	0.993	0.991	0.972	0.975
Labourer	0.986	0.989	0.989	0.986	0.954	0.963

Source: ABS, Occupation by Journey to Work (JTW), custom data from Census 2001.

Table 2: Commuting distance by occupation (kms), Sydney, Melbourne and Brisbane CAs, 2001.

	Actual	*Random*	*Max*	*Min*	*Xcess*	*R/ Xcess*	*Actl/ Rand*	*Rank-ing*
				Sydney				
Managers	15.72	28.76	37.35	9.85	37.34	21.34	54.64	1
Professionals	14.57	28.74	37.12	9.18	36.99	19.29	50.70	2
Associate Professionals	15.25	31.92	41.49	10.24	32.83	16.02	47.76	3
Tradespersons	16.00	36.22	47.77	10.39	35.09	15.02	44.17	4
Advanced Clerical, Sales & Service	14.83	31.57	41.16	11.09	25.20	12.43	46.97	7
Intermediate Clerical, Sales & Service	14.98	32.14	42.07	10.58	29.40	13.99	46.62	6
Intermediate Production & Transport	15.01	34.01	44.55	9.92	33.88	14.69	44.14	5
Elementary Clerical, Sales & Service	13.08	35.01	46.19	9.43	27.95	9.94	37.37	9
Labourer	13.84	36.33	47.85	9.28	32.91	11.80	38.08	8
TOTAL	**14.84**	**32.34**	**42.43**	**9.84**	**33.66**	**15.33**	**45.87**	
				Melbourne				
Managers	9.59	18.64	23.85	4.31	55.09	27.04	51.47	2
Professionals	8.24	15.44	19.59	3.54	57.07	29.32	53.40	1
Associate Professionals	9.02	18.51	23.70	4.42	50.95	23.83	48.70	3
Tradespersons	9.92	22.50	30.12	4.67	52.94	20.62	44.08	5
Advanced Clerical, Sales & Service	8.81	18.45	23.63	4.86	44.83	21.06	47.77	6
Intermediate Clerical, Sales & Service	8.95	18.30	23.72	4.78	46.63	22.05	48.92	4
Intermediate Production & Transport	9.50	21.28	29.19	4.67	50.91	19.73	44.65	6
Elementary Clerical, Sales & Service	7.86	20.04	26.40	3.98	49.46	17.35	39.25	9
Labourer	8.85	22.66	30.55	4.32	51.21	17.27	39.05	8
TOTAL	**8.89**	**19.00**	**24.71**	**4.24**	**52.32**	**22.72**	**46.77**	
				Brisbane				
Managers	14.15	32.44	39.48	7.80	44.86	20.04	43.62	4
Professionals	10.68	18.87	23.71	4.92	53.93	30.64	56.58	1
Associate Professionals	11.71	22.67	28.86	6.52	44.34	23.25	51.67	2
Tradespersons	13.27	27.14	36.15	6.98	47.40	21.55	48.87	3
Advanced Clerical, Sales & Service	10.61	22.11	28.00	7.14	32.73	16.65	48.00	7
Intermediate Clerical, Sales & Service	11.39	22.63	29.32	6.84	39.97	20.24	50.32	4
Intermediate Production & Transport	13.27	27.83	37.31	7.63	42.48	19.00	47.67	6
Elementary Clerical, Sales & Service	9.82	23.89	31.61	5.69	42.12	15.96	41.12	8
Labourer	12.73	31.52	41.44	7.35	42.28	15.78	40.38	9
TOTAL	**11.75**	**24.46**	**31.48**	**6.40**	**45.54**	**21.34**	**48.04**	

Source: ABS, Occupation by Journey to Work (JTW), custom data from Census 2001.

TP. Adopting Charron's methodology, the urban form corresponding to each occupation is proxied by the minimum commute, so that the comparison of minimum commutes across occupations reflects their differential degree of job proximity, which could be a consequence of locational constraints reflecting housing affordability.

The alternative would be to explore the key worker hypothesis simply by documenting summary statistics based on actual commuting behaviour, ignoring any distinction between the morphological and behavioural components. The higher skilled tend to have longer commutes (Simpson, 1992; Giuliano and Small, 1993) which may reflect the associated urban form, and specifically their larger 'local' labour market, but could also reflect the discretionary component of commuting, reflecting a range of socio-

economic characteristics, which are briefly described at the beginning of the paper. Thus simple cross-section comparisons of average distance commuted would not be very insightful in identifying whether certain workers are being forced to commute further.

Column one presents the actual average commute for each broad one-digit occupation. We find that the average distances commuted are much higher in Sydney and Brisbane than in Melbourne, even though urban Brisbane SLAs tend to be smaller.[4] Second, Tradespersons, Managers and Associate Professionals tend to have the longest average commutes, which, with the exception of Managers in Sydney and Melbourne, translate into the highest minimum commutes. Thus other considerations such as schooling, location of friends and relatives and the amenity of the chosen residential area may take precedence over a strategic choice of location designed to minimize average commutes, particularly when transport costs for a self-employed Tradesperson would be tax deductible. The uncertainties of work location for Tradespersons may contribute to their high average commute. On the other hand, low-skilled Elementary Clerical, Sales and Service workers typically have the lowest average commute. Thus the evidence is not convincing that minimum commutes are systematically higher for the low-skilled occupations.[5]

As explained in the Data and Methodology section, the minimum commute represents the underlying urban form. It represents the average commute if workers in each occupation chose the residential location corresponding to the overall minimum average commute for each occupation. For all occupations and cities the minimum commute is below the actual commute as expected. Sydney has a much higher minimum commute than Melbourne and Brisbane which indicates that Sydney workers live further away from their place of employment as determined by the underlying distribution of housing and jobs. There is minimal variation across occupations, with Professional workers tending to have slightly shorter minimum commutes and Advanced/Intermediate Clerical, Sales and Service workers having slightly longer minimum commutes.

Tradespersons and the higher-skilled occupations, including Professionals, tend to be associated with higher rates of excess commuting, which is the component of commuting that is not determined simply by job proximity. This indicates greater freedom of choice for higher-income workers with respect to residential location, and also that high-skilled workers have higher incomes which offset the costs of longer commutes.

The maximum commutes by occupation are consistently higher in Sydney, followed by Brisbane and Melbourne. This ranking would reflect both the respective geographical areas covered by the CAs and the associated spatial distribution of housing and jobs. The Sydney CA has the smallest land area, namely 15,664 km^2 (compared to 238,099 km^2 in Brisbane[6] and 21,346 km^2 in Melbourne) but is likely to have a more uniform density of housing and jobs over this area. On the other hand, the relative magnitudes of intra-CA maximum commutes by occupation just reflect the respective spatial distributions of housing and jobs. A high average maximum commute, relative to corresponding minimum commute would imply that the associated housing and jobs were widely dispersed over the CA. This would provide tentative evidence of housing affordability not being a major constraint for the particular occupational group.[7] Across the three CAs, Tradespersons, Labourers and Intermediate Production and Transport workers (and also Managers in Brisbane and Elementary Clerical, Sales and Service workers in Sydney and Melbourne) have the highest maximum commutes.

Three relative measures of commuting are also reported by occupation and in total in table 2. They are measures of excess and relative excess commutes, as defined previously, and the ratio of actual commutes

to PMC. High values for the relative measures indicate a significant volitional component to the pattern of commuting. The occupations in each CA were also ranked according to the three relative measures and a composite ranking which is shown in the right-hand column of table 2 was obtained from adding together the three rankings for each occupation. Thus we can clearly see that in all three cities, excess or volitional commuting is highest amongst high-skill occupations, namely Managers, Professionals (despite consistently low average and minimum commutes) and Associate Professionals, and medium-skilled Tradespersons. There is also weaker evidence with respect to Intermediate Production and Transport workers. On the other hand, Advanced and Elementary Clerical, Sales and Service workers and Labourers exhibit the lowest volitional component, but, whereas in Sydney and Melbourne Elementary Clerical, Sales and Service workers and Labourers have low average and minimum commutes, only Elementary Clerical, Sales and Service workers in Brisbane have low actual and minimum commutes. Curiously Advanced Clerical, Sales and Service workers typically have high minimum commutes across the capital cities, which may reflect compromises being made by households about residential location. The less clear cut results for Brisbane, particularly with respect to Managers, may be indicative of the less constraining impact of housing affordability. Relative and absolute rates of excess commuting are quite highly correlated, so there is little additional insight gained from the calculation of the maximum commute.

The ratio of actual to random commutes gives a measure of the extent to which workers successfully minimize their commutes compared to the commute that would result if workers were randomly allocated. Professional and Managerial occupations have the smallest actual commutes relative to the commuting distance which would eventuate from a random allocation.

Conclusion

The analysis of commuting patterns is complex and beset with difficulties of interpretation because commuting flows are the outcome of interdependent decisions about residence and employment made by members of households. This paper has explored the conceptual issues surrounding the interpretation of commuting patterns and provides a preliminary investigation of occupational differences in commuting patterns for the three most populated State capitals in Australia. The key worker hypothesis has gained increasing traction in Britain and the US in the past few years, but, so far, does not have strong empirical support in Australia. In part this reflects the fact that skill shortages and the peak of the housing boom occurred after 2001, when the Census data were collected. A more thorough analysis will be possible when the 2006 ABS JTW data become available, and also when more spatially disaggregated data can be used.

We have argued that, while the conceptual distinction between the morphological and behavioural components of commuting is problematic, it does make sense to focus on the component of commuting based on the 'urban form' corresponding to the particular occupation, which at least removes the inefficient component of the average commute, given the associated spatial distribution of housing and jobs. Furthermore, any discussion of excess commutes ought to recognize that household location decisions are jointly determined by household members. Two-income households are more common, and these generate multi-stage commuting decisions, with, for instance, one partner commuting short distances and the other(s) longer distances. Moreover, transport costs are not confined to those incurred during the journey to work, so that the potential length and cost of journeys for social, leisure, retail and perhaps medical purposes may well impact on the residential

location and possibly employment decision, although these data on transport costs are not available from the Census. For example, suburban residents may be willing to experience longer journeys to work, which translate into higher rates of excess commuting, if travel costs for non-work purposes are likely to be less than those borne by inner-city dwellers.

Taking into account the demanding assumptions of the Transportation Problem, our tentative conclusions are as follows.

Average actual and minimum commutes are much higher in Sydney than in Melbourne and Brisbane, suggesting that job-proximity is poorer in this city, even when account is taken of the 'volitional' or excess component of commuting. For Sydney, Melbourne and Brisbane actual commutes appear to be highest for Professionals and Tradespersons and lowest for Elementary Clerical, Sales and Service workers, and lowest also for Labourers in Sydney and Melbourne.

Our descriptive work seems to lend support to Yates (2005) and Yates *et al*. (2006) who find little evidence that low-skill occupations have lower levels of employment accessibility, as evidenced by a longer minimum commute, and is in contrast to the notion that housing affordability problems are lengthening commutes for low-income and low-skill workers pushed to the city fringe.

The derived minimum commutes thus provide little support for the underlying hypothesis that lower-skilled workers have higher minimum commutes due to the locational constraints imposed by housing affordability. This is likely to reflect the ambiguous overall impact on locational choice of housing affordability which impacts on lower-income workers and the tendency for the local labour markets of the more highly-skilled to be larger.

The formal analysis of commuting patterns for the employed indicates some consistency across the three cities with respect to the occupational variation in the relative commuting statistics. Higher-skilled occupations have a greater volitional component of commuting than low-skilled occupations. This finding is supported by the argument that high-income workers are able to bear the costs of lengthy commutes and have more choice of location for workplace and residence.

Our results importantly highlight the need to separate out the job-related and volitional components of commuting, given that high-skill and high-income workers may be influenced by factors other than straightforward job-proximity in choosing their residential location. This is illustrated by greater excess commutes observed for this group. It is likely that there is a significant trade-off emerging between commuting cost and time and housing affordability, particularly for the low-skilled.

As noted earlier, it is questionable whether Charron's claim about the morphological and behavioural components of commuting can be substantiated, particularly when disaggregating by occupations. If high-quality income data by occupation were available through the Census, then the minimum commute corresponding to a particular occupation could take explicit account of housing affordability, rather than relying on occupational status, which ignores the presence of intra-occupational income inequality.

NOTES

1. We discuss the justification for this terminology in a later section of the paper.

2. The analysis of recent HILDA data reveals that housing and personal reasons outrank work-related factors in determining where people move (Bill and Mitchell, 2006)

3. We argue against the term Functional Economic Area because it prejudges the economic significance of this form of spatial disaggregation. The origin of the term Local Labour Market lies in the identification of the labour catchment area for a large employer or a spatial cluster of smaller establishments (Morrison, 1990, pp. 510–511), so it too is inappropriate.

4. Comparison of the average area of the SLAs comprising each CA is somewhat distorted by large outer suburban SLAs, particularly in Queensland.

5. Further analysis of average distance commuted for two-digit occupations in 2001, for Sydney, Melbourne and Brisbane CAs was also undertaken (where distance was again computed 'as the crow flies' from centroid of origin SLA to destination SLA). Again there appeared to be little variation in distance commuted between occupations. Across the three cities, thus there would seem to be little support for the notion that unskilled and elementary workers (cleaners, labourers and related workers, factory labourers and elementary service workers) are facing longer commutes than high- and medium-skill workers. Also for those groups who have been specifically targeted as key workers (teachers, nurses and health service workers), commutes do not appear to be significantly above average, and in some instances are well below average. This analysis does not break the actual commute down into minimum and excess commutes.

6. Seven outlying SLAs in the Brisbane CA account for over 225,000 km^2. Four outlying SLAs account for nearly 6,280 km^2 of the Melbourne CA and 3 outlying CAs account for over 8,000 km^2 of the Sydney CA.

7. If housing and jobs were mainly located in different areas, then the relative differential between the maximum and minimum commute would be small, as compared to housing and jobs sharing the same areas, when the minimum commute would be relatively low, compared to the maximum commute.

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