

# Los Angeles employment concentration in the 21st century

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## Abstract

This paper is an empirical analysis of employment centres in the Los Angeles region from 1997 to 2014. Most extant work on employment centres focuses on identification methodology or their dynamics during a period of industrial restructuring from 1980 to 2000. We analyse employment centres using point-based, rather than census tract-based employment data and a non-parametric identification method with a single concept of proximity. We focus on changes across five key industries: knowledge-intensive business services (KIBS), retail, creative, industrial and high-tech, emphasising changes in centre composition as well as their boundaries. Results show far greater change across centres than previous longitudinal studies. Only 43% of the land area that is in an employment centre is part of one in both 1997 and 2014. Using a persistence score, centres range from stable to highly fluctuating, but emerging, persisting and dying centres are found in core and fringe areas alike. KIBS are most associated with stable centres, while high tech employment is attracted toward emerging areas and retail exists throughout. Emerging centres are more likely to have greater accessibility, while industrial employment becomes far more concentrated in centres by 2014.

## Keywords

Los Angeles, industrial structure, agglomeration economies, employment centres, land-use change

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## Introduction

The study of what drives concentration and dispersion of economic activities in urban areas is no less important today than it was

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at any point since Von Thunen's 1826 publication of *The Isolated State* (1966). However, the study of polycentricity and centres of employment concentration by a variety of urban scholars largely remains rooted in 20th century theory making use of 20th century data. Ideas about polycentricity and edge cities, popularised by books such as Garreau (1991) and seminal papers such as Giuliano and Small (1991) largely flow from late-20th century concepts about the transition to a post-industrial service economy (see, e.g. Scott, 1988), the 'death of Geography' that will be brought about by globalisation and information and computing technologies (ICT), and the impact of perpetually decreasing transportation costs (see, e.g. Anas et al., 1998). Empirical studies of 20th century employment concentration generally highlight persistence over time (Redfearn, 2009), emphasising longstanding ideas about the path dependence of economic landscapes (Arthur, 1988). Most employment centres are heavily conditioned by the location of prior hubs of economic activity, particularly within the Los Angeles region (Forstall and Greene, 1997; Redfearn, 2009).

Changing patterns of employment concentration since the 1980s have often been linked to producer services or knowledge-intensive business services (KIBS), given the role that information technology has had on the intraurban spatial distribution of this typically office-based work that became more prevalent following de-industrialisation (Coffey, 2000). In addition to KIBS, high-tech growth has been persistently targeted as a local and regional development strategy, often in the form of research parks or technopoles (Link and Scott, 2015). Urban economies have also been acknowledged for their role as sites of consumer activity, with a specific emphasis on the advantages of globally connected metropolises and within-city districts featuring unique cultural outputs

(Florida, 2002; Glaeser et al., 2001; Scott, 1997). Popularised in part by Florida (2002), a related trend emphasises the importance of a 'creative class' of knowledge workers to the local economy. These high-skill individuals prefer more 'authentic' urban experiences in addition to shopping, arts and recreation. A prime example of the interplay between the producer and consumer sides of the urban economy is the increasing tendency of employers to move headquarter locations to downtown areas in order to recruit the talented members of the knowledge economy who value proximity to transit and other urban amenities not found in dispersed areas or isolated suburban office parks (Core Values, 2015). In addition to evolutions in the nature of production and consumption, the field of urban planning offers a number of contemporary perspectives regarding intraurban concentration specifically. The New Urbanism and Smart Growth movements both emphasise how multiple, interconnected centres of employment can contribute to reduced commute time, transportation expense, energy use and an increased sense of place (Duany et al., 2010; Knaap and Talen, 2005), while an increased focus on the sustainability of urban areas has raised substantive concerns over environmental degradation – both locally in the form of land change and pollution but also globally in terms of climate change (see, e.g. Alberti, 2005).

This paper presents an examination of employment centres in the Los Angeles area over a 17-year period during the early years of the 21st century in order to observe the impact of contemporary changes in the urban economy on the spatial distribution of employment concentration. An emphasis is placed on the idea of the stability of centres, following from the contention that employment concentration is an extremely durable long-term phenomenon in cities (Redfearn, 2009), and that changes in urban

neighbourhoods comprise two separate components: boundary change and compositional change (Rey et al., 2011). McMillen and Smith (2003: 332) define an employment centre in general terms as 'an area with significantly higher employment densities than surrounding areas that is large enough to have a significant effect on the overall spatial structure of the urban area'. Methodologically, this paper adopts a two-stage non-parametric approach to employment centre identification in the spirit of McMillen and Smith's definition using a combination of locally weighted regression and contiguity relationships in a GIS environment. Following Leslie (2010), we sidestep the more common use of census tracts to delineate centres and instead use point-based data on individual business establishments from 1997 to 2014 in order to identify areas of concentration that are statistically distinct from surrounding areas. This high-resolution approach is more adept at capturing the location patterns and location choices of individual businesses. We analyse composition based on five key industry types: KIBS, retail, creative, industrial and high-tech. The choice of the Los Angeles area follows a long history of the study of employment concentration here beginning with Giuliano and Small (1991), while the region's status as a large, car-oriented metropolis with a mild climate is consistent with many drivers of the urban resurgence that began in the 1990s (Glaeser and Gottlieb, 2006).

## Literature review

### *Concentration and dispersion of employment*

Agglomeration economies have long been considered the key driver of the concentration of economic activity (Marshall, 1890; Rosenthal and Strange, 2004). While they are used to explain the existence of cities and urban hierarchy, the benefits of co-location

also influence the internal spatial structure of individual urban regions (Agarwal et al., 2012). The traditional monocentric city model of urban economics posits high rents at the city centre which decrease with distance owing to the co-location benefits accruing to a downtown location, while polycentricity is an extension stating that agglomeration economies can also accrue to other regional centres of activity, in part to avoid the congestion costs associated with a single centre. Such employment centres can also be functionally specialised, with certain industries realising agglomeration benefits in particular centres or particular industries driving patterns of concentration (Fujii and Hartshorn, 1995; Leslie and Ó hUallacháin, 2006). A contrasting perspective is that of Gordon and Richardson (1996), who argue that the prevailing forces in the location of economic activity – namely, decreasing transportation costs and the rise of ICT – contribute to a dispersion or 'scatteration' of activity rather than concentration in multiple nuclei. Coffey and Shearmur's (2002) study of higher-order business services in Montréal suggests this position may be too extreme despite trends toward telecommuting and the suburbanisation of back office functions, finding that this key sector continues to agglomerate but in auxiliary centres rather than the region's main downtown.

While not much attention has been paid to locational shifts of employment centres, some studies have found them to be very stable over time, suggesting deep agglomerative underpinnings. Redfearn's (2009) thorough examination of concentration from 1980 to 2000 shows that present-day centre location can be explained accurately based on deeply lagged indicators of infrastructure and economic activity such as the original interstate highway map from 1942 or the location of significant places from the turn of the 20th century. Arthur (1988) distinguishes between proximity to capital-intensive fixed

infrastructure and chance historical occurrences in the emergence of industrial concentration; nonetheless, the belief that urban spatial pattern is heavily path-dependent is widely held. Gradual changes in the location of economic activity might result from economic restructuring, as Gordon and Richardson (1996) demonstrate through the impact of ICT on employment centres, but less commonly explored – perhaps since it requires finer resolution data – is the role that land-use change and real estate development have on employment concentration. Longcore and Rees' (1996) study of the advertising and financial services industries in Manhattan describe their move from Wall Street to Midtown as a response to demand for new office buildings featuring better tech connectivity and larger floor plates – both seen as essential to modern businesses. Weber's (2015) study of commercial office space in Chicago emphasises that aggressive leasing brokers and the financialisation of the real estate market led to an oversupply of commercial office space (despite increasing vacancy rates), resulting in a spatial shift of Class A office space from the East Loop district toward Wacker Drive. The same concept of obsolescence, whether real or somewhat manufactured, can apply to the land use needs of other sectors too, particularly retail. For example, the rise of big box stores fundamentally changed the demand for older, enclosed shopping malls (Lorch and Hernandez, 2008).

### *Production and employment concentration*

Producer services, or knowledge-intensive business services (together referred to as KIBS in this paper for brevity), have long been associated with studies of polycentricity (Coffey, 2000). Since KIBS are higher-order office-based activities that rely on face-to-face contact they were historically located in CBDs, though innovations in IT during the

1990s led to hypotheses of their suburbanisation (Gordon and Richardson, 1996). Forstall and Greene's (1997) study of Los Angeles indicates a slight deconcentration of KIBS through the 1980s. More recently KIBS have been studied for their innovative capacity (Herstad and Ebersberger, 2014; Shearmur, 2012). Shearmur (2012) finds that some KIBS activity such as R&D may be more innovative if dispersed – further reason to postulate their continued suburbanisation. Nonetheless, the high-skill, high-wage, and metropolitan-oriented nature of KIBS has made them attractive as a component of economic development policy (Coffey and Polèse, 1989; Lundquist et al., 2008).

High-tech employment in both manufacturing and services is also targeted for its potential to foster local economic development. The iconic examples of Silicon Valley and Boston's Route 128 reflect both an interurban and intraurban component of agglomeration economies accruing to high-tech industry (Saxenian, 1994). Numerous policy initiatives – many of which explicitly seek 'the next Silicon Valley' – support local science parks, research parks, technopoles and tech incubators in order to foster job growth and technology transfer (Tamásy, 2007). A wide body of empirical and theoretical literature has emerged on the mixed success of such policies (Link and Scott, 2015; Shearmur and Doloreux, 2008). Spencer (2015) draws a distinction between the intraurban patterns of science-based technologies and creative-oriented industries across Canadian cities, suggesting that the former are more concentrated in low-density suburban campuses while the latter are more prevalent in mixed-use areas or urban cores. Nonetheless, the continuing evolution of high-tech industry merits longitudinal analysis of its intraurban patterning.

Finally, manufacturing – particularly defense manufacturing – was a major component in the rise of the Southern California

economy during the Second World War and the Cold War (Levy, 2000) but has seen a substantial decline since the 1990s. Historically manufacturing has gravitated toward lower-rent locations along the urban fringe (Kain, 1968). However, modern forms of flexible or just-in-time production are thought to affect the typical spatial distribution of manufacturing activity (Scott, 1988), while easy access to transportation infrastructure is increasingly important for logistics operations (Audirac, 2002).

### *Consumption and employment concentration*

Cities are increasingly functioning as centres of consumption as well as production. In the USA, the amount of personal consumption expenditures has grown dramatically over the last several decades and currently accounts for over two-thirds of GDP (McCully, 2011). As Glaeser et al. (2001) note, these growing consumption activities are likely to take place in highly urbanised areas where people enjoy a wide array of goods and services, natural amenities, pleasant aesthetics and high-quality public services. Providing consumer amenities, sometimes in the form of reducing crime or other types of disamenities, has become crucial to the success or resurgence of places and central cities in particular (Glaeser and Gottlieb, 2006). Shopping behaviour, measured using retail employment, is considered as a component of polycentric urban development by Fujii and Hartshorn (1995). Chapple and Jacobus (2009) emphasise the role of retail in neighbourhood revitalisation and thus the possibility that retail concentration might reflect a form of urban infill. Zukin (2004), however, emphasises the perpetual strength of shopping malls and suburban town centres, following longstanding ideas about comparison shopping in retail geography (Hotelling, 1929; Nelson, 1958).

Thus, concentration in retail might reflect greenfield or infill development.

Consistent with the consumption-oriented perspective on urban retail, a broader trend of urban amenitisation and revitalisation is often linked to the locational preferences of so-called 'creative class' workers who are seen as key components of a revitalised local economy (Florida, 2002; Kolenda and Liu, 2012). As such, creative employment might be expected to cluster in centres (or downtowns in particular) heavy in retail, dining, arts and entertainment, consistent with Spencer (2015). In addition to the main downtown, relatively dense suburban mixed-use centres and the smaller downtowns of inner-ring suburbs have been locations of attempts at densification for the same reasons (Filion, 2001). Citing such trends, a wide array of corporations have been moving headquarter and branch locations to downtown areas in part to attract and retain talented workers of the knowledge economy. A survey of corporations who recently moved to downtown areas in the USA found that, in addition to brand image, collaborative opportunities and proximity to other related businesses (i.e. traditional agglomeration economies), these recruitment benefits were increasingly valued in their location choices (Core Values, 2015). Such a trend reflects mutual reinforcement between densification trends on both consumer and producer sides of the economy.

### *Perspectives on planning*

While the discussion of employment concentration thus far has emphasised the spatial outcomes of economic sectors' propensity to concentrate, contemporary movements in urban planning can also inform the understanding of concentration in general, particularly at a fine spatial scale where city planners, real estate developers and other stakeholders are involved in the production

of suitable space for economic activity. New Urbanism and Smart Growth are two distinct movements that began in earnest in the mid-1990s with a common goal of addressing problems created by urban sprawl (Knaap and Talen, 2005). While New Urbanism's focus on architecture and urban design contrasts with Smart Growth's emphasis within planning organisations, both stress the importance of directing growth toward areas with existing infrastructure and already concentrated activity rather than remote locations. Regions developed with such principles in mind are thought to enjoy an increased sense of place, a wider variety of housing choices, less redundant infrastructure and reduced vehicle miles travelled, while addressing environmental concerns is a key motivator of both New Urbanism and Smart Growth (Duany et al., 2010). In addition, Sustainable Cities movements within planning, landscape ecology and related fields emphasise the connections between growing urban footprints and local and global environmental change (Haughton and Hunter, 2004; Grimm et al., 2008), and advocate directing growth toward existing, more concentrated areas to reduce ecological disturbance alongside design-related improvements such as reduced surface impermeability and increased reflectivity. To our knowledge, empirical research has not specifically linked such contemporary movements with employment concentration specifically, nor is such an undertaking the explicit goal of this study. However, rising concentrations in existing areas would suggest that recent development patterns are generally consistent with their ideas.

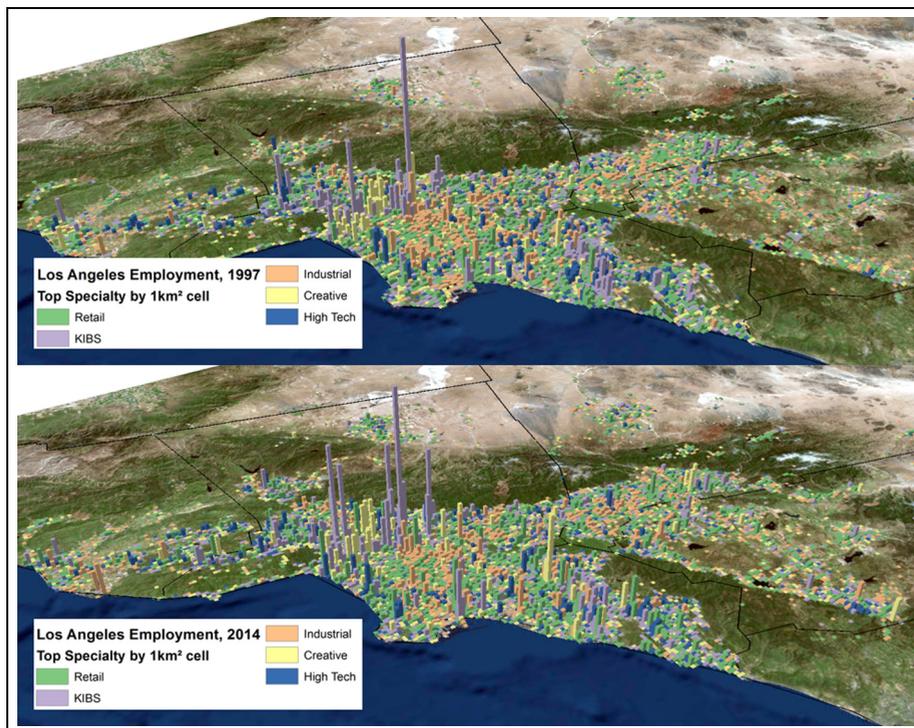
## Methods and data

This study examines the evolution of employment centres between 1997 and 2014

by applying an identification method to spatially explicit business establishment data. Recent research has taken up the cause of improving methodological approaches to identifying employment centres within a metropolitan area. We sidestep a thorough review (for a more detailed treatment, see Agarwal et al., 2012), though the most notable difference in approach is whether to use a fixed threshold for density and total employment in a centre (i.e. the original approach of Giuliano and Small, 1991) or to use a regression-based approach that offers more flexibility and statistical robustness (McMillen, 2001; Redfearn, 2007). However, because of factors including the delineation and size of census tracts, the importance of a region's central business district (CBD), and disagreement over what is really considered 'local', there is no one true method for employment centre identification. This paper adopts a two-stage non-parametric regression-based approach most similar to Redfearn (2007) but with some modifications to account for the different data source.

## Data source

The data used here are Reference USA point-based establishment data covering 1997–2014 (Infogroup, 2015), which provide coordinate data, an employee count and the North American Industry Classification System (NAICS) code for every business establishment region-wide. A total of 4.67% of business establishments could not successfully be geocoded: in these cases, the centroid of the ZIP code in which the business lies was used as a proxy. Given our focus on recent trends in urbanism, we rely on these data's timeliness, contrasting them with other recent studies such as Agarwal (2015) and Arribas-Bel et al. (2015) which use year 2000 data.



**Figure 1.** Los Angeles region employment density, 1997–2014.

### *Employment centre identification*

While point-based establishment data are the ‘gold standard’ for avoiding the modifiable areal unit problem, measuring points based on employment *density* necessitates their aggregation to a two-dimensional unit. We create a 1 km × 1 km fishnet, or grid of cells covering the urbanised extent of the region and use GIS to spatially join the establishment and employment figures to these cells. Cells have the advantage of being consistent in size and are designed to represent the region’s urbanised space that could theoretically contain an establishment. While most US studies of urban areas use combined metropolitan statistical areas (CMSAs) from the Census Bureau, the LA region’s counties of Los Angeles, Orange, Riverside, San Bernardino and Ventura

include vast swaths of rural and uninhabited land. To circumvent this problem, we use 30 m resolution remotely sensed imagery from the National Land Cover Database (Homer et al., 2015) to identify cells in the five-county area which have at least 10% urbanised land cover.<sup>1,2</sup> Figure 1 shows the employment density of the 16,144 cells representing land in the area that could in theory contain establishments.

The first step in the non-parametric identification of employment centres, following McMillen (2001), is to estimate a locally weighted regression which uses nearby employment densities to create a surface of predicted employment for each cell. Local maxima are identified as observations whose actual employment is significantly higher (using a  $p < 0.01$  standard) than that

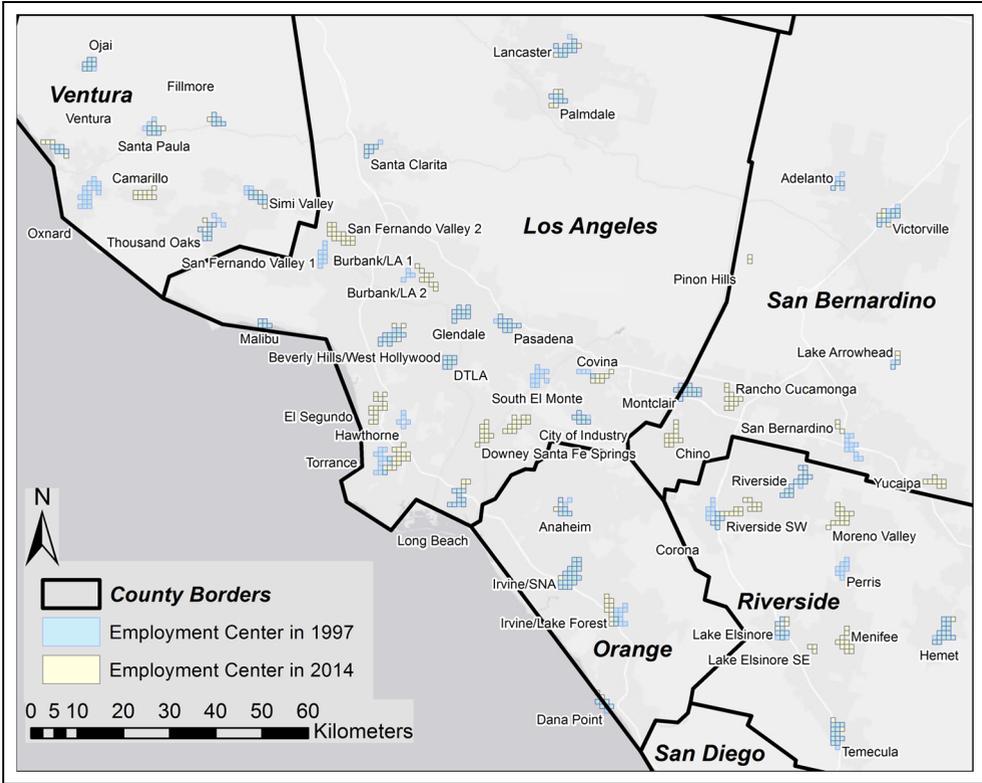
predicted by the locally weighted regression. A kernel is used to smooth the sample over a certain proportion of the observations: McMillen (2001) chooses to smooth employment using 50% of the observations in the urban area, while Redfearn (2007) uses the nearest 1% of the observations. We take advantage of the gridded nature of our observations to use a single concept of proximity: 120 nearest neighbours. This amounts to a smaller neighbourhood definition of about 0.7% of the sample and should result in local maxima that are more regularly spaced – consistent with the notion of centres as ‘areas of higher density than areas nearby’. Within a 1 km<sup>2</sup> grid, 120 nearest neighbours represents five cells in each direction and results in cells within 6.08 km being considered as neighbours. The median cell in this study area has neighbours spanning 7.28 km, with the higher figure reflecting the impact of the grid’s edges. In some extreme outlying areas neighbour distances exceed 80 km. Since each neighbourhood may contain more than one local maximum, the final selection of local maxima only includes cells whose employment density is higher than all of its 120 nearest neighbours.

The second step is to identify the cells surrounding each local maximum which will form the boundaries of each distinct employment centre. We diverge slightly from Redfearn (2007) and adopt a spatial weights matrix approach similar to McMillen (2003). Using the 120 nearest neighbour definition, we define an employment centre as a contiguous region surrounding each local maximum where each member (1 km<sup>2</sup> cell) has a higher employment density than its neighbours. A contiguity weights matrix is then used to loop through all cells contiguous to each local maximum and add to the employment centre any cells with higher than the neighbourhood’s average employment. The process is repeated for cells contiguous to those just identified until all

possible cells within the local maximum’s 120-neighbour neighbourhood are evaluated. Of the 16,144 cells encompassing the Los Angeles region, 445 (2.76%) were part of an employment centre in 1997 and 530 (3.29%) were part of an employment centre in 2014 (Figure 2). A robustness test using 4 km<sup>2</sup> and 0.25 km<sup>2</sup> grid cells was conducted and is detailed in Appendix A. We also replicate the analysis using census tracts; however, substantial overdispersion in the distribution of their sizes makes comparison difficult. Furthermore, we believe a grid cell approach which treats all urban area equally is most consistent with McMillen and Smith’s definition that centres should reflect areas with significantly higher density than their surroundings.

### Exploratory analysis

After identifying employment centres, we perform exploratory spatial and statistical analysis to understand employment concentration dynamics. While centres are identified based on the concentration of total employment, employment is subsequently analysed across five separate industries. We use a slightly broader version of Shearmur and Alvergne’s (2002) definition of KIBS, covering Professional, Scientific and Technical Services (NAICS 54), Information (NAICS 51), Finance and Insurance (NAICS 52), and Educational Services (NAICS 61, excluding primary and secondary education, 61111). Following Kolenda and Liu’s (2012) analysis of intrametropolitan creative industries, we employ a simple definition of *creative class* employment as Information (NAICS 51) and Arts, Entertainment, and Recreation (NAICS 71). While this is a fairly crude definition of creative employment, it reflects components of an innovative workforce and consumption-based employment, both thought to be a component of vibrant cities. *Retail* (NAICS 44 and 45) is combined with



**Figure 2.** Los Angeles region employment centres, 1997–2014.

Accommodation and Food Services (NAICS 72) to capture employment in consumption and consumer-facing industries. *High-tech* employment is defined by Cortright and Mayer (2001) as Computer and Electronic Product Manufacturing (NAICS 334), Software Publishing (NAICS 5112), Data Processing and Hosting (NAICS 518), and Computer Systems Design (NAICS 5415). Finally, *industrial* employment consists of Manufacturing (NAICS 31-33), Utilities (NAICS 22), and Mining, Quarrying, and Oil and Gas Extraction (NAICS 21). Net of overlap, these five categories cover 52.4% of the region’s total employment in 1997 and 50.7% in 2014.

First, we will examine employment trends within versus outside of centres. Compositional change overall and in centres

will be analysed using location quotients following Leslie (2010), which compare a centre’s share of an industry type with that industry’s share region-wide. Formally, the location quotient for sector  $i$  at location  $j$  is given by:

$$LQ_i^j = \frac{E_i^j / \sum_i E_i^j}{E_i / \sum_i E_i} \quad (1)$$

where  $E_i^j$  is the employment in sector  $i$  at location  $j$  and  $E_i$  is the total employment in sector  $i$  region-wide. Location quotients can be compared across individual centres, and between centres and non-centres.

Next, we will analyse boundary and compositional change treating employment centres as discrete entities. Centres are given names based on the US Census-designated

**Table 1.** Employment in/out of subcentres

	1997	2014	Percent growth
Number of centres	46	53	15.2%
Size of centres (km <sup>2</sup> )	445	530	19.1%
Centre employment	1,092,461	1,588,345	45.4%
Total employment	6,261,171	8,095,136	29.3%
Percent in centre	17.4%	19.6%	12.5%

Note: Overall persistence score: 0.4317.

place in which their local maximum lies, using local knowledge in cases where a place name repeats or is otherwise unclear. A persistence score is used to analyse the level to which a centre's boundaries remain consistent or change over time. Adapting a measure of persistence from Pontius et al. (2004) commonly used in ecological land change analysis, persistence for centre  $i$  is given by:

$$Persist_i = \frac{center_{t-1} \cap center_t}{center_{t-1} \cup center_t} \quad (2)$$

where the numerator represents cells that are common to the centre  $i$  in time  $t$  and time  $t-1$  and the denominator represents all cells in centre  $i$  at either time.

We also explore some region-wide trends using cells as observations to improve causal inference. Using ANOVA, cells' membership in an employment centre is compared with their proximity to the region's core, proximity to transportation infrastructure, distance to the Pacific Ocean, county, and propensity to specialise in any of the five employment categories.

## Results

### Overall employment concentration

Using 1 km<sup>2</sup> cells, we identified 46 employment centres in 1997 and 53 employment centres in 2014, with 14 new centres emerging (30%) against seven dropping out of

the set (15%). This is fairly consistent with previous work such as Giuliano et al. (2007) who find 48 centres in the region in 2000. As Table 1 indicates, centres represent a fairly small proportion of total employment though this share grew from 17.4% in 1997 to 19.6% in 2014. However, growth in centres outpaced overall employment growth in this period 45.4% versus 29.3%.

Results appear somewhat sensitive to cell size, and a full discussion is provided in Appendix A. Replication of the analysis using 4 km<sup>2</sup> cells results in fewer, less dense centres which cover more land area and a larger portion of total employment, while 0.25 km<sup>2</sup> cells result in fewer, denser centres covering less land area. 1 km<sup>2</sup> cells appear most comparable with previous regression-based centre identification studies, which have generally been tailored to ensure a fairly consistent number of centres in the region – approximately 40 to 50 (Agarwal et al., 2012). Since the use of 1 km<sup>2</sup> grid cells maintains this consistency and is at approximately the 30th percentile of the size distribution of the region's tracts, the remaining analysis focuses on this resolution alone.

### Overall industrial structure

Certain industries also exhibit a changing propensity to exist in centres versus non-centres (Table 2). One-fourth of KIBS employment, which increases region-wide

**Table 2.** Sectoral employment by centre.

	1997			2014		
	Employment	Centre employment	Centre percent	Employment	Centre employment	Centre percent
KIBS	1,054,885	264,454	25.1%	1,440,656	361,208	25.1%
Retail	1,323,133	230,986	17.5%	1,840,616	373,226	20.3%
Creative	285,030	46,718	16.4%	479,256	83,566	17.4%
Industrial	889,489	138,991	15.6%	687,580	137,252	20.0%
High tech	178,821	30,374	17.0%	138,576	35,637	25.7%
Total	6,261,171	1,092,461	17.4%	8,095,136	1,588,345	19.6%
	Percent of employment in centres	Percent of total employment	Location quotient	Percent of employment in centres	Percent of total employment	Location quotient
KIBS	24.2%	16.8%	1.437	22.7%	17.8%	1.278
Retail	21.1%	21.1%	1.001	23.5%	22.7%	1.033
Creative	4.3%	4.6%	0.939	5.3%	5.9%	0.889
Industrial	12.7%	14.2%	0.896	8.6%	8.5%	1.017
High tech	2.8%	2.9%	0.973	2.2%	1.7%	1.311

and in centres, is located in centres in both 1997 and 2014. While KIBS (business services) are more likely to exist in employment centres, their propensity for concentration decreases over the study period from a location quotient of 1.437 to 1.278. This supports the contention that agglomeration economies such as face-to-face communication are decreasingly important for business services, consistent with theories of the scatteration of back-office components of business operations. However, they are still far more likely to exist in centres than non-centres. High-tech employment actually decreases across the region, but most of this is in the NAICS 334 subcategory comprising tech manufacturing. High tech employment in centres and the high tech location quotient in centres both increase; the latter rising from 0.973 to 1.311. While region-wide industrial employment decreases substantially, the amount of industrial employment in centres stays nearly identical and its location quotient increases from 0.896 to 1.017 – concentration is increasingly important for

industrial employment despite historic expectations of suburbanisation.

The portion of employment that exists in centres increases from 17.4% to 20.3% and retail's location quotient increases slightly from 1.001 to 1.033. This suggests a slight increase in retail concentration though it does not indicate whether this increase takes place in existing or new centres. Contrary to expectations of creative employment's urban-centric nature, creative employment is less likely than average to exist in centres, with a location quotient of 0.939 that decreases to 0.889 by 2014. While creative employment increases substantially region-wide, the bulk of this growth does not appear to be in centres. It may be that creative amenities, consumption spaces and creative output are not best measured by employment. Lower-rent areas with less concentrated employment, neighbourhoods in transition or agglomeration shadows may be advantageous for businesses that characterise the creative class; however, the use of 2-digit NAICS codes is admittedly coarse.

### Boundary change

While comparing centres versus non-centres is informative, analysing individual employment centres based on their stability over time helps us to understand the changing forces of concentration and dispersion. Figure 2 shows the location of centres across the region in 1997 and 2014. While the land area of employment centres increased from 445 km<sup>2</sup> to 530 km<sup>2</sup>, only 294 km<sup>2</sup> was common to both periods, yielding an overall persistence score of 0.4317 (Table 1). This finding illustrates how employment centres emerged, died, grew and contracted at a finer scale, contrasting with previous tract-level studies such as Redfearn (2009) which found high levels of stability over time. Persistence scores vary by spatial scale as well, ranging from 0.288 using 0.25 km<sup>2</sup> grid cells to 0.6154 using 4 km<sup>2</sup> grid cells, while persistence using 1 km<sup>2</sup> cells is fairly comparable with the 0.5019 value for tract-level persistence (see Appendix A). This also contrasts with Leslie's (2010) fine-scale, establishment-level findings, which concluded that point-derived employment centres in Phoenix, Arizona were largely stable from 1995 to 2004 but does not use a persistence score.

Table 3 shows persistence scores for all 60 individual employment centres. Five centres do not experience any boundary change and have the maximum persistence score of 1. These include downtown Los Angeles and downtown Glendale – two historically embedded and stable core areas. Some smaller centres also experience full persistence including Malibu, a 27-mile long corridor along the Pacific coast to the northwest of Los Angeles. It is identified as a centre mostly because its densest 5 km<sup>2</sup> is denser than the rest of Malibu. Blythe, a small town near the Arizona border, is similar in that its status as a centre is largely due to its location far from other centres while its full persistence makes sense in the context of the

town's age and stability. Montclair also exhibits full persistence and is a three-city employment centre spanning the Los Angeles–San Bernardino county line, though its persistence is not readily explained by its history or location.

What may be more unexpected is the prevalence of low-persistence centres. The minimum persistence score of zero is displayed by the fourteen new centres in 2014, as well as the seven centres that ceased to exist – no area was in common to both years. Furthermore, 30 of the 60 centres at any time have a persistence score at or below 0.5. Torrance, one of the region's larger centres, has the lowest (non-zero) persistence score, with only 2 km<sup>2</sup> out of 28 remaining the same. Whereas in 1997 employment in Torrance was concentrated farther east along a major arterial road, employment density has crept farther east toward the junction of two freeways (I-405 and I-110). The Covina, Corona, San Fernando Valley, and Burbank/LA employment centres show similar processes of directional shifting. In fact, San Fernando Valley and Burbank/LA are each two distinct centres since their extents in 1997 and 2014 are not contiguous. In 1997, the 4 km<sup>2</sup> centre labelled Burbank/LA 1 represented the local employment density peak and consisted mainly of strip retail. By 2014 the local peak in employment density was a strip along Interstate 5 stretching from Burbank's commercial airport to its historic downtown core.

Two employment centres in Orange County provide a contrast between persisting and shifting employment centres (Figure 3). The northern centre extends from John Wayne Airport (SNA) to include parts of Irvine, Santa Ana, Costa Mesa and Tustin and is widely known as a business headquarter location, housing firms such as Western Digital and Taco Bell. The 1997 and 2014 versions of this employment centre

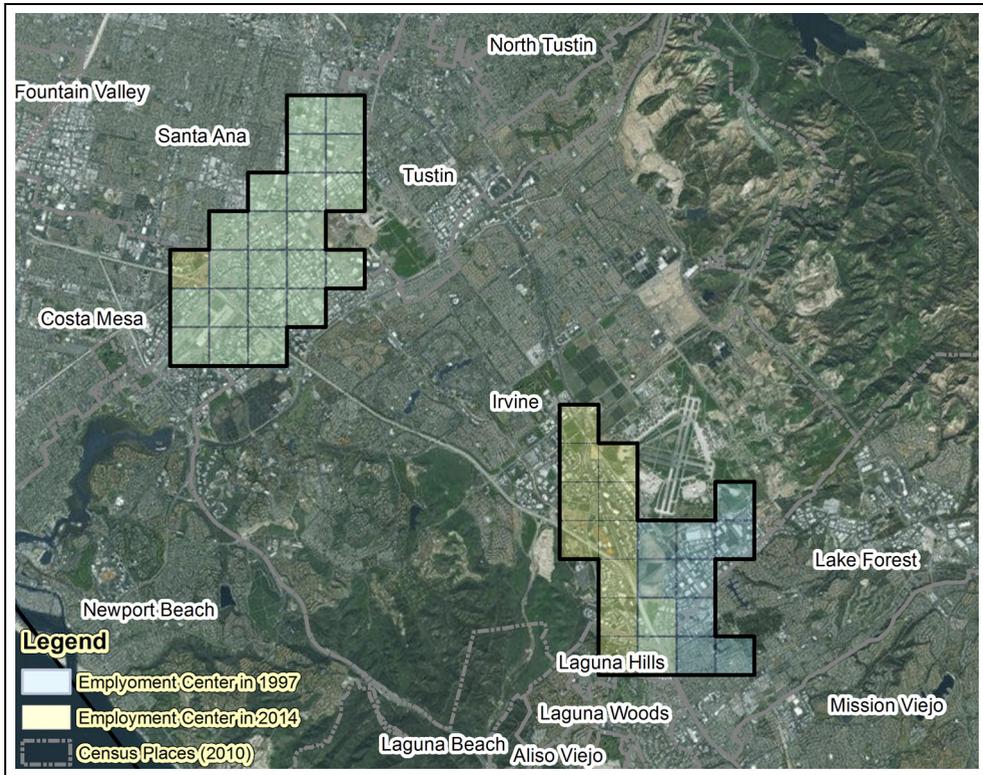
**Table 3.** Employment centres, sorted by total employment in 2014.

Name	1997 Employment	2014 Employment	1997 (km <sup>2</sup> )	2014 (km <sup>2</sup> )	Total (km <sup>2</sup> )	Persistence score	Status	1997– highest LQ	2014– highest LQ
Downtown LA	163,118	161,850	8	8	8	1	Persists	KIBS	KIBS
Beverly Hills/W Hollywood	113,030	158,930	13	15	16	0.75	Persists	KIBS	Creative
Irvine/SNA Airport	126,321	139,972	21	22	22	0.955	Persists	High tech	High tech
Glendale	51,647	86,457	11	11	11	1	Persists	Retail	KIBS
Pasadena	58,916	83,518	12	11	12	0.917	Persists	KIBS	KIBS
El Segundo	Non-centre	69,540	0	14	14	0	Emerges	High tech	High tech
Irving/Lake Forest	27,840	65,638	11	12	21	0.095	Persists	High tech	High tech
Torrance	51,760	53,841	13	17	28	0.071	Persists	High tech	Industrial
San Fernando Valley 2	Non-centre	52,690	0	16	16	0	Emerges	High tech	High tech
Santa Fe Springs	Non-centre	41,334	0	13	13	0	Emerges	Industrial	Industrial
Riverside	35,226	36,676	16	15	16	0.938	Persists	KIBS	KIBS
Temecula	19,731	36,539	13	14	15	0.8	Persists	Retail	Industrial
Corona	16,606	36,166	13	13	20	0.3	Persists	Industrial	Industrial
Downey	Non-centre	35,782	0	11	11	0	Emerges	Industrial	Retail
Anaheim	20,587	34,506	8	7	10	0.5	Persists	High tech	Creative
Long Beach	23,326	33,614	10	12	13	0.692	Persists	Retail	High tech
Burbank/LA 2	Non-centre	29,603	0	9	9	0	Emerges	Creative	Creative
Montclair	24,862	28,731	13	13	13	1	Persists	Retail	Retail
City of Industry	17,492	27,989	8	7	8	0.875	Persists	Industrial	Retail
Rancho Cucamonga	Non-centre	26,680	0	11	11	0	Emerges	Industrial	Industrial
Ventura	11,193	25,312	6	10	10	0.6	Persists	Retail	Retail
Chino	Non-centre	22,745	0	12	12	0	Emerges	Industrial	Industrial
Riverside SW	Non-centre	20,601	0	7	7	0	Emerges	Retail	Retail
Lancaster	15,780	20,070	13	14	15	0.8	Persists	Retail	Retail
Palm Springs	13,589	19,936	11	14	17	0.471	Persists	Retail	Creative
Palm Desert	20,149	19,852	11	9	12	0.667	Persists	Retail	Retail
Thousand Oaks	12,225	19,205	11	10	13	0.615	Persists	Retail	Retail
Simi Valley	14,846	18,699	11	10	13	0.615	Persists	High tech	Retail
Camarillo	Non-centre	17,510	0	10	10	0	Emerges	High tech	High tech
Covina	6641	17,231	4	8	11	0.091	Persists	Creative	Retail
Santa Clarita	10,074	15,086	7	6	7	0.857	Persists	Retail	Retail
Hemet	13,831	14,833	16	16	17	0.882	Persists	Retail	Retail

(continued)

Table 3. Continued

Name	1997 Employment	2014 Employment	1997 (km <sup>2</sup> )	2014 (km <sup>2</sup> )	Total (km <sup>2</sup> )	Persistence score	Status	1997– highest LQ	2014– highest LQ
Moreno Valley	Non-centre	13,928	0	14	14	0	Emerges		Retail
Victorville	14,151	13,605	11	12	15	0.533	Persists	Creative	Retail
Palmdale	4256	11,773	6	10	10	0.6	Persists	Retail	Retail
Dana Point	6289	9101	7	7	9	0.556	Persists	Retail	Retail
Menifee	Non-centre	6712	0	11	11	0	Emerges		Retail
Barstow	4838	6149	8	9	9	0.889	Persists	Retail	Retail
San Bernardino	25,631	6060	11	3	14	0	Persists	KIBS	Creative
Lake Elsinore	3191	5825	9	11	13	0.538	Persists	Retail	Retail
Big Bear Lake	3356	5797	12	11	14	0.643	Persists	Retail	Retail
Yucaipa	Non-centre	4778	0	8	8	0	Emerges		Retail
Santa Paula	5805	4719	9	8	11	0.545	Persists	Industrial	Industrial
Banning	2182	4685	8	6	9	0.556	Persists	Creative	Retail
Ojai	3551	4278	8	7	8	0.875	Persists	Retail	Retail
Malibu	3133	4150	5	5	5	1	Persists	KIBS	KIBS
Blythe	3760	3586	8	8	8	1	Persists	Retail	Retail
Fillmore	2139	2732	6	7	7	0.857	Persists	Retail	Retail
Adelanto	1380	2640	6	3	6	0.5	Persists	Industrial	Industrial
Lake Elsinore SE	Non-centre	1808	0	3	3	0	Emerges		Retail
Lake Arrow head	1284	1758	3	4	5	0.4	Persists	Retail	Creative
Yucca Valley	1906	1725	4	4	5	0.6	Persists	Retail	Retail
Pinon Hills	Non-centre	1400	0	2	2	0	Emerges		Retail
San Fernando Valley I	57,946	Non-centre	9	0	9	0	Dies	High tech	
Oxnard	26,885	Non-centre	18	0	18	0	Dies	Retail	Retail
South El Monte	23,706	Non-centre	12	0	12	0	Dies	Industrial	Industrial
Hawthorne	11,325	Non-centre	5	0	5	0	Dies	High tech	High tech
Burbank/LA I	10,097	Non-centre	4	0	4	0	Dies	Industrial	Industrial
Perris	4768	Non-centre	9	0	9	0	Dies	Industrial	Industrial
Needles	2092	Non-centre	7	0	7	0	Dies	Retail	Retail



**Figure 3.** Contrasting employment centre boundary changes in Orange County.

overlapped by 95% – a 1 km<sup>2</sup> addition in Santa Ana was the only change for 2014. The centre further south surrounds the former El Toro Marine Air Corps Station and only has 2 km<sup>2</sup> of overlap between its 1997 and 2014 versions. In 1997 this employment centre was characterised by a variety of light industry and small businesses surrounding two major arterial roads. However, the opening of the Irvine Spectrum Centre shopping mall in the late nineties shifted the concentration of local employment eastward toward a freeway junction (I-5 and I-405). The local employment density maximum is now the mall area rather than the commercial corridor. Dynamism in a centre's boundaries can be experienced by small, medium and large centres alike.

### *Compositional change*

While the previous section demonstrates fluctuating employment centre boundaries, this section investigates changes in the industrial composition of individual centres. The rightmost two columns of Table 3 indicate for each centre the industrial sector (KIBS, retail, creative, industrial or high tech) with the highest location quotient in order to gauge which of these key industries is most specialised there. For most centres, retail displays the highest location quotient, indicating its prevalence in centres region-wide. Twenty-three employment centres in 1997 (50%) and 28 centres in 2014 (53%) can be considered 'retail-driven'. This label is fairly persistent as well – only five such centres become more specialised in something else.

These include the well-diversified Long Beach centre whose industrial and tech LQs increase substantially, the destination towns of Lake Arrowhead and Palm Springs who shift toward creative employment, and a slight industrial uptick in Temecula. Poignantly, City of Industry shifts from an industrially-dominated employment centre to retail. Seven of the 14 'emerging' centres were retail-dominated.

The increasing tendency of industrial employment to concentrate is also reflected in centre-level location quotients. Three new employment centres (Chino, Rancho Cucamonga and Santa Fe Springs) are industrially dominant, while Temecula's focus shifts from retail to industrial and Torrance's focus shifts from high tech to industrial. Similar to the region-wide results presented earlier, KIBS tend to show a decrease in prevalence in employment centres. Six centres are principally characterised by KIBS employment in 1997, though San Bernardino and Beverly Hills/West Hollywood see their focus switch to creative by 2014. While some of this can be attributed to the overlap between the KIBS and creative employment categories, only three centres display both an increase in KIBS location quotient and a value above 1: Irvine/SNA Airport, Irvine-Lake Forest, and Torrance. Note that these results comment on a centre's location quotient across the five categories considered, not its total employment in any industry.

Creative class employment has the highest location quotient in three decidedly non-central employment centres in 1997: Victorville, Banning and Covina. In contrast, by 2014 six distinctive centres are characterised principally by creative employment in 2014: Anaheim, the weekend retreats of Palm Springs and Lake Arrowhead, Beverly Hills/West Hollywood, San Bernardino and Burbank. Consistent with the decline in high-tech manufacturing

employment discussed earlier, the high-tech concentration across the seven tech-dominant centres in 1997 appears to have dissipated: only Irvine/SNA and Irvine/Lake Forest remain tech-dominant in 2014. Both the old and new San Fernando Valley centres are tech-dominated, airport-adjacent El Segundo and Camarillo emerge as tech centres, and Long Beach shifts from a retail to a tech focus.

Furthermore, these compositional changes at the centre-level implicitly take boundary change into account. For example, while Torrance's dominant employment category shifts from tech to industrial, its footprint changed dramatically too (with persistence score of 0.07). The 1997 boundaries of the Torrance centre were characterised by retail, industrial and high tech employment which declined. The area extending eastward from the 1997 centre boundaries experienced similar industrial and tech declines but in contrast made up for them with substantial increases in KIBS and retail employment, meriting inclusion as part of the employment centre in 2014. While still characterised by heavy industry, Torrance is an example of a centre whose locus of employment shifts both spatially and compositionally.

### *Region-wide patterns*

While analysing individual employment centres provides rich detail about the evolving economic geography of the region, using 60 observations which vary dramatically in size and importance is not conducive to statistical inference. This section analyses the 681 1-km<sup>2</sup> grid cells that were part of an employment centre in either 1997 or 2014. Only 294 cells were part of a centre in both years. A simple ANOVA test is conducted to compare emerging, persisting and dying cells based on their proximity to the Los Angeles' downtown, freeways, passenger rail, airports

**Table 4.** Analysis by individual cells ( $n = 681$ ).

<b>a. ANOVA by Location</b>					
	Mean-dying cells	Mean-emerging cells	Mean-persisting cells	ANOVA $p$ -val	Significant Pairs
km to L.A. CBD	80.54	60.94	80.97	0.0001	emerges-dies, persists-emerges
km to Freeway	2.90	1.94	4.34	0.0001	persists-emerges
km to Airport	24.50	11.59	26.64	0.0001	emerges-dies, persists-emerges
km to Coast	51.05	39.22	53.90	0.0025	persists-emerges
km to Rail	40.63	25.53	36.96	0.0000	emerges-dies, persists-emerges

<b>b. Persistence Scores by County</b>					
County	Dying	Emerging	Persisting	Total cells	Persistence score*
Orange	14	15	31	60	0.52
Riverside	30	57	84	171	0.49
Ventura	28	21	41	90	0.46
Los Angeles	50	97	92	239	0.38
San Bernardino	29	46	44	119	0.37

<b>c. Location Quotients by Persistence</b>					
	KIBS	Retail	Creative	Industrial	High tech
Dying cells ( $n = 151$ )	1.01	1.00	0.62	1.12	1.61
Emerging cells ( $n = 236$ )	0.91	1.10	1.01	1.43	2.24
Persisting cells ( $n = 294$ )	1.49	1.00	0.82	0.78	0.78

Note: \*Chi-square value of 18.13 with 8 degrees of freedom is significant at  $p = 0.0203$

and the Pacific coast (Table 4a).<sup>3</sup> Proximity to downtown provides a crude measure gauging whether cells are located centrally or nearer the urban fringe, while proximity to the Pacific Coast is a strong determinant of land price and indicates a major regional amenity. Cells comprising emerging employment centres are about 20 km closer to the CBD than either persisting or dying cells – a significant difference. Emerging areas are also significantly closer to freeways, airports, rail lines and the Pacific coast. This is unsurprising since airports, freeways and rail lines tend to co-locate. There are no significant locational differences between

persisting areas and dying areas. Overall, these results suggest that new, growing places of employment concentration are more discerning with their location choices and are significantly nearer to existing infrastructure, region-wide amenities, and less toward the urban fringe.

County-level locational trends are also easily examined and help to parse between core and fringe areas (Table 4b). While Los Angeles County is clearly the region's core, Orange County is considered to be fairly well-established. While the cities of San Bernardino and Riverside are long-standing, the counties which bear their names are

archetypical urban fringe areas and are referred to as the 'Inland Empire', while Ventura County is far smaller in population. A chi-squared test on the first three columns of Table 4b yields a significant value of 18.13, indicating that there is variation in the level of persistence by county. While San Bernardino County has the lowest persistence at 0.37, Los Angeles County is not far behind at 0.38. Orange and Riverside Counties are notably higher in terms of persistence with values of 0.52 and 0.49. These results do not correspond to the general perceptions of counties as core or peripheral – flux appears to exist throughout the region.

Table 4c contains the final analysis of cells by persistence, investigating whether cells that emerge, persist or die tend to specialise. Location quotients are calculated relative to *total* employment in the sector rather than centre-only employment. The substantially higher LQ for KIBS in persisting areas again highlights this sector's relationship with stability. Trends in retail, creative and industrial employment mirror previous results: all are more specialised in emerging areas, though retail is more weakly specialised in emerging areas and creative employment shows low specialisation in any kind of employment centre. The high tech sector continues to demonstrate a strong propensity toward emerging locales (LQ of 2.24) versus 0.78 for persisting and 1.61 for dying areas, indicating high churn.

## Discussion and conclusions

The purpose of this study was to examine changes in the composition and spatial distribution of employment centres across the Los Angeles region based on 21st century changes in the urban economy. The employment centre identification method used is particularly reflective of local instances of high density, while the use of point-based data provides a more realistic view of

individual businesses' location decisions as well as changes in the boundaries of centres. The use of a non-parametric identification technique is adept at distinguishing *local* peaks in employment density, defined as areas within about 7 km.

First, the dominant feature of employment concentration over 1997–2014 is change rather than core-area stability, especially when investigated using a cell-based method that treats all urban space equally. Not only do centres emerge and die region-wide, the boundaries of employment centres change substantially in core and fringe areas alike which contrasts markedly with prior longitudinal studies. The economic landscape is not characterised by core areas gradually expanding and increasing in density. There are clearly some persistent centres that remain vibrant such as downtown Los Angeles, Irvine/SNA, Glendale and Beverly Hills/West Hollywood. However most areas are more in-flux. Places such as Irvine/Lake Forest, Torrance and Burbank highlight the gradual spatial shifts that accompany the interplay between economic shifts and the real estate cycle. In Irvine/Lake Forest a new shopping mall shifted the locus of regional employment away from a more producer-oriented corridor, while in Torrance industrial increases overshadowed nearby losses in tech concentration. In Burbank, employment concentration gravitated toward the city's historic downtown. Future research could isolate the role of both policy and individual real estate developments in some of these concentration shifts. We find some evidence that emerging areas of employment concentration are closer to LA's downtown, freeways, airports, rail lines and the Pacific coast when compared with persisting or dying areas of concentrated employment. Fixed infrastructure, centrality and this regional amenity clearly play a role in where employment grows. Since these are long-term, fixed components of the urban landscape, this

result suggests strong path-dependence despite changes since 1997 – a reassurance for proponents of Smart Growth.

In terms of industrial structure, KIBS employment remains an important component of stable employment centres, though overall KIBS are decreasingly found in concentrated areas, consistent with theories surrounding the role of IT or innovation surrounding KIBS dispersion. However, KIBS' strong association with persisting centres and persisting cells suggests somewhat of a resilience to locational economic changes, which could justify the policy-makers' focus on attracting business services owing to their more lasting nature. High-tech employment is now most concentrated in centres and particularly in newly emerging parts of centres – this even though employment in tech manufacturing has been decreasing. This provides some evidence that growth in employment concentration is heavily related to high-tech activity in new and established centres alike. However, high-tech employment exhibits more locational dynamism, suggesting that while investments in science parks or technopoles could promote increased job concentration, high-tech may not always be the best target for long-term, stable local economic development. Industrial employment demonstrates an increasing propensity to agglomerate in centres despite its overall decline, which may speak to the resilience of the manufacturing employment that does remain: flexible or just-in-time production modes may benefit more from agglomeration, and in particular from proximity to fixed infrastructure. Alternatively, the most economically competitive (thus, remaining) industry could have location advantages by being in centres. Given the shuttering of much of the region's defence and aerospace manufacturing industries after the Cold War, this makes sense but might be specific to the Los Angeles area.

Like high-tech, retail employment and retail location represent an increasing share of what drives regional employment concentration. This is consistent with the idea of consumption-focused cities – more than half of the region's new centres are more specialised in retail than anything else. This speaks to the power of 'emerging town centres' – which in the Irvine/Lake Forest example shown is in fact a large shopping mall and its hinterland. Creative employment is fairly loosely defined in this study but is not primarily found in centres and is in fact decreasingly concentrated in centres. The distinctiveness of some of the region's creative-oriented centres (Disneyland is in the Anaheim centre, while the Burbank and Beverly Hills/West Hollywood centres house major movie studios) may be a reflection of the idiosyncrasies of Southern California's creative employment base – i.e. television, film and a globally known recreation destination – making any conclusions regarding creative employment regionally specific. At a minimum, it is clear that employment counts in creative industries are not the same thing as the class of amenity-seeking 'knowledge workers' described by Florida and can vary across regions. Much of the thinking on creative employment and the amenitisation favoured by knowledge workers is associated with downtown revitalisation. While some loft conversions and arts districts have been noted in Los Angeles' downtown, if anything distinctive about it stands out in this study it is its persistent boundaries and persistent KIBS-orientation. It is the largest centre by only a narrow margin, and the region is known for housing cultural amenities elsewhere. Government employment, unexplored in this study, is known to be high in downtown LA and could be an important consideration here and in other regions, especially if job creation policies are at all oriented toward the public sector.

By following the simple logic that ‘centres are areas of employment density greater than their surroundings’, we find substantial changes hidden behind the overall increase in centres: of the 445 km<sup>2</sup> of land in centres in 1997, only 294 km<sup>2</sup> remains in a centre by 2014. Previous tract-level research on the same region covering the 1980s and 1990s found far more employment centre stability, but did not explicitly consider changing boundaries or persistence. While our robustness check suggests that the resolution at which analysis is conducted matters, all grid cell sizes in this study – as well as census tracts – exhibited substantial boundary change. Future studies should be careful to use geographies that treat all urban space equally. An added benefit of this approach is that it avoids the pitfalls of using fairly few individual employment centres as observations, which does not offer adequate statistical robustness. Finally, this study suggests some caution against the contention that future growth will necessarily favour existing concentrated areas. Employment concentration continually fluctuates and while growth in employment centres outpaces growth overall, the vast majority of new jobs lie outside centres despite increasing emphasis on Smart Growth policy and urban sustainability. Policymakers should be keenly aware of leveraging local strengths and locational advantages, while also paying attention to what kind of employment may be most lasting.

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### Notes

1. While studies such as Redfearn (2007) use census-defined Urban Areas (UAs) to exclude uninhabited land, we found numerous instances of clearly urban business establishments outside UA boundaries. Since the definition of UAs relies on residential census block population, certain establishments were missed. This was most prevalent in coastal and inland recreational areas such as Malibu and Lake Matthews.
2. NLCD land cover categories 21, 22, 23, and 24 as of 2011 were considered urban in this analysis. See Homer et al. (2015).
3. Los Angeles city hall is used to define the region's CBD and is at 34°03'11"N, 118°14'27"W. Passenger rail consists of Los Angeles Metro and Metrolink commuter rail stations.

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## Appendix A: Employment centre sensitivity to spatial scale

In order to provide a measure of robustness and justify the selection of 1 km<sup>2</sup> grid cells for this analysis, we replicated the analysis using 4 km<sup>2</sup> cells, 0.25 km<sup>2</sup> cells and census tracts. First, in order to maintain a roughly consistent concept of proximity analogous to the 6–7 km threshold used for 1 km<sup>2</sup> cells, it was necessary to modify the 120 nearest neighbour criterion. Using 36 nearest neighbours for 4 km<sup>2</sup> cells and 484 nearest neighbours for 0.25 km<sup>2</sup> cells roughly mirrors the range used for identification of local maxima and centre boundaries.

We also replicated the analysis using census tracts; however, substantial overdispersion in the distribution of census tract sizes ( $\mu = 14.5 \text{ km}^2$ ,  $\sigma = 174 \text{ km}^2$ ) makes generating a consistent proximity concept impossible. Additionally, the NLCD-based urban area identification procedure is incompatible with tracts since many tracts with businesses also contain large natural areas and would have urban land coverages below 10%. We follow through with the analysis but instead use tracts within the five county area's US Census urbanised area boundaries. Results for all resolutions and tracts can be found in Table A1.

Results appear somewhat sensitive to cell size. Replication of the analysis using 4 km<sup>2</sup> cells results in fewer centres which cover more land area and a larger portion of total employment, while 0.25 km<sup>2</sup> cells result in fewer centres covering far less land area. At this fine resolution the number of centres actually decreases between 1997 and 2014; however, total employment in centres rises, suggesting that smaller grid cells detect a much denser form of employment concentration. Thus, it's clear that each cell size represents a distinctly different concept of 'employment concentration'. This is a

component of employment centres that could not be realised in previous tract-level studies.

Tract boundaries induce other problems because their sizes and shapes are inconsistent. Their far lower employment density, shown in Table A1, reflects the non-urbanised areas contained within tract boundaries. However, while tract-level centres include a higher percent of regional employment than 1 km<sup>2</sup> centres, it is worth noting that both the growth in centre employment and the growth in centre percent of employment are nearly identical.

Since the region's street grid is comprised mainly of arterial roads spaced at half-mile increments (which would divide the urban space into 0.65 km<sup>2</sup> units), 0.25 km<sup>2</sup> resolution appears too small to capture employment concentration; for example, a suburban corporate campus is likely larger than this but could record all its employees at a single point. Furthermore, an identified local maximum could be a single office building with high employment. A somewhat smaller office building across a wide arterial road might not even be in a contiguous cell at this resolution, opening up the possibility of missing key auxiliary portions of employment centres.

Figure A1 and Table A2 show the Ventura employment centre, which illustrates the region-wide patterns found in Table A1, i.e. the existence of fewer, smaller, denser centres at finer resolution and the existence of fewer, larger, less dense centres at coarse resolution. Only the highest-density 'core' of the centre appears at 0.25 km<sup>2</sup> scale. At 1 km<sup>2</sup>, the region identified as a centre has a footprint four times as large, while at 4 km<sup>2</sup> a large portion of land to the south meets the criteria for having a 'higher density of jobs' than its surroundings and is therefore included as part of the centre. At this resolution, the centre is six times larger. Since the

**Table A1.** Employment in/out of subcentres.

	1997	2014	Percent growth
<b>a. 1 km<sup>2</sup> grid cells</b>			
Number of centres	46	53	15.2%
Size of centres (km <sup>2</sup> )	445	530	19.1%
Centre employment	1,092,461	1,588,345	45.4%
Total employment	6,261,171	8,095,136	29.3%
Percent in centre	17.4%	19.6%	12.5%
<i>Overall persistence score: 0.4317</i>			
<b>b. 4 km<sup>2</sup> grid cells</b>			
Number of centres	31	33	6.5%
Size of centres (km <sup>2</sup> )	924	1,008	9.1%
Centre employment	1,870,206	2,484,263	32.8%
Percent in centre	29.9%	30.7%	2.7%
<i>Overall persistence score: 0.6154</i>			
<b>c. 0.25 km<sup>2</sup> grid cells</b>			
Number of centres	46	39	-15.2%
Size of centres (km <sup>2</sup> )	111	107	-3.6%
Centre employment	336,637	450,347	33.8%
Percent in centre	5.4%	5.6%	3.5%
<i>Overall persistence score: 0.2880</i>			
<b>d. 2010 Census tract boundaries</b>			
Number of centres	54	64	18.5%
Size of centres (km <sup>2</sup> )	1961	2799	42.7%
Centre employment	2,405,380	3,465,000	44.1%
Percent in centre	38.4%	42.8%	11.4%
<i>Overall persistence score: 0.5019</i>			

**Table A2.** Ventura Employment Centre (2014).

	0.25 km <sup>2</sup>	1 km <sup>2</sup>	4 km <sup>2</sup>
Number of cells	10	10	15
Total land area (km <sup>2</sup> )	2.5	10	60
Centre employment	9308	25,312	98,875
Centre emp. dens. (jobs/km <sup>2</sup> )	3723	2531	1648

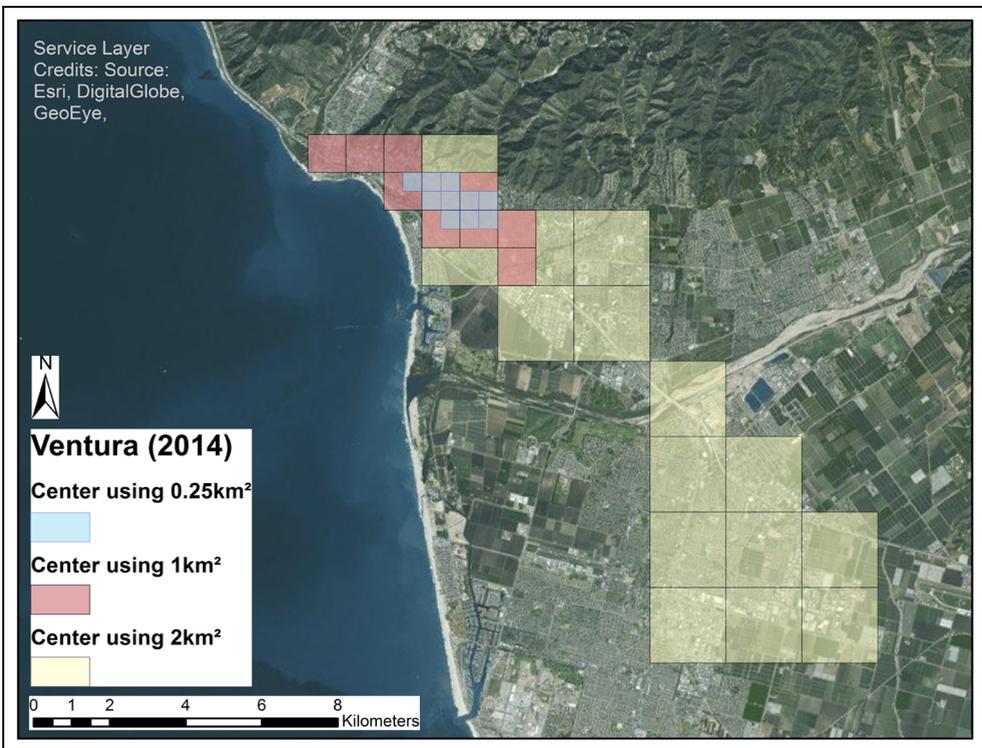
36 km<sup>2</sup> area to the south is more suburban in nature than the core of downtown Ventura, it is likely to consist of a different industry mix than the subcentre as conceived at 0.25 km<sup>2</sup> or 1 km<sup>2</sup> resolutions.

Anas et al. (1998) remark that subcentre boundaries are quite sensitive to definition, saying 'the urban landscape is highly irregular when viewed at a fine scale ... It may be that the patterns that occur at different distance scales are influenced by different types

of agglomeration economies, each based on interaction mechanisms with particular requirements for spatial proximity' (p. 1440). In the context of the present study, this suggests that KIBS, industrial, high-tech, or other individual sectors may have a propensity to agglomerate that exists most acutely at a particular scale. The present study identifies subcentres based on total employment, not on sector employment and comments more directly on urbanisation economies of

**Table A3.** Sectoral centre employment and share by scale (2014).

	0.25 km <sup>2</sup>		1 km <sup>2</sup>		4 km <sup>2</sup>	
	Emp. in centres	% of Emp. in centres	Emp. in centres	% of Emp. in centres	Emp. in centres	% of Emp. in centres
KIBS	108,236	24.03%	361,208	22.74%	526,297	21.19%
Retail	108,257	24.04%	373,226	23.50%	525,831	21.17%
Creative	15,755	3.50%	83,566	5.26%	183,757	7.40%
Industrial	34,769	7.72%	137,252	8.64%	222,390	8.95%
High tech	6100	1.35%	35,637	2.24%	44,358	1.79%
Total	450,347		1,588,345		2,484,263	



**Figure A1.** Ventura Employment Centre (2014).

scale rather than localisation economies of scale. A future study which identifies KIBS centres, tech centres, and industrial sectors based on employment in the sector alone and irrespective of other employment may be better at finding the scales of the different

types of agglomeration economies proposed by Anas et al.

Nonetheless, Table A3 attempts a crude measure of distinguishing the scale at which sector-specific agglomeration economies might operate. For each scale, the sectoral

employment that is in subcentres is displayed, as well as the share of total centre employment each sector represents. Shares appear mostly robust across scales. An exception is creative employment, which represents a higher share of centre employment at a coarser resolution. However, the idiosyncratic nature of creative employment in Los Angeles, driven by the television and film industries as well as regional-level attractions such as Disneyland, might limit the applicability of this result to other regions.

In summary, 1 km<sup>2</sup> cells appear most comparable to previous regression-based

centre identification studies. Studies of Southern California have generally been tailored to ensure a fairly consistent number of centres in the region – approximately 40 to 50 (Agarwal et al., 2012). Since the use of 1 km<sup>2</sup> grid cells maintains this consistency, and is at approximately the 30th percentile of the size distribution of the region's tracts, the remaining analysis focuses on this resolution alone. A Monte Carlo approach using a simulated spatial distribution of employment might be the most appropriate method for future research to analyse the scale at which employment concentration occurs.