Technical Appendix

Details of the Data

We retrieved parcel-level land use data sets for 2008 and 2016 from SCAG for all 180 cities in five Southern California counties (Los Angeles, Orange, Riverside, San Bernardino, and Ventura). SCAG is the largest metropolitan planning organization in the United States and covers 191 cities in the six-county Southern California region that comprises Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties. We focused on cities in only the five *urban* counties and did not include seven cities in Imperial County, which is a rural county, in our study. Further, we excluded cities such as Eastvale and Jurupa Valley that incorporated after 2008 from our study because we examined land use change for incorporated cities from 2008 and 2016. SCAG uses a consistent classification method and its own land use codes to categorize parcels in cities, which facilitates a comparison of the land use profiles of cities over time. We retrieved parcel-level land use data for 2016, available online from the SCAG GIS Open Data Portal, that explains the details of the data, as follows:

> This is the draft version of SCAG's 2016 land-use dataset, updated as of November 2018, including general plan land use, specific plan land use, zoning code and existing land use. Please note this data was reviewed by local jurisdictions and reflects each jurisdiction's input received during the SCAG's 2020 RTP/SCS Local Input and Envisioning Process.
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> SCAG worked with the region's 197 local jurisdictions to refine this information during the Bottom-Up Local Input and Envisioning Process beginning in summer 2017. Data contained here reflects local feedback, and is to be used for research purposes. Official information on land use should be obtained from each local jurisdiction directly. (SCAG, n.d.a)

Next, we sent an email to senior regional planners at SCAG, describing the objectives of our research, and requested access to parcel-level land use data for 2008 that could be compared

with the 2016 data available from SCAG. We retrieved a comparable parcel-level land use data set for 2008 from the Dropbox link that the SCAG regional planners provided.

SCAG's 2008 land use data set includes parcel-level data and information on general plan land use as well as zoning data for all 180 cities; however, only the general plan land use data follow a consistent land use code system across all cities. Although the 2016 land use data set includes parcel-level information on the existing land use, general plan land use, specific plan land use, and zoning, we used parcel-level general plan land use data for 2008 and 2016, given the comprehensive coverage of parcels in the data sets and their comparability across 2008 and 2016. It is noteworthy that the general plan land use data include designated future land use as well as existing land use by jurisdiction. Given that most of the region is already urbanized, the general plan land use data for 2016 for most of the cities in the region include a smaller proportion of designated future land use and a much larger proportion of existing land use. In addition to general plan land use data, we used specific plan land use data to determine detailed land use in specific plan areas. In California, specific plans are adopted as detailed policies or as regulations to implement the policies of the local general plan in a specific portion of the city. SCAG has categorized parcel-level general plan land use data for 2008 into 41 land use codes and the data for 2016 into 136 land use codes. The general plan land use data available from SCAG for 2008 do not differentiate between various types of multifamily residential land use, which precludes a comparison of different types of multifamily land use across 2008 and 2016. Given this, we aggregated parcel-level general plan land use data from SCAG for 2008, and for 2016, into the following eight major land use categories: 1) single-family residential, 2) multifamily residential, 3) mixed use, 4) commercial, 5) industrial, 6) open space, 7) institutional and public facility, and 8) other.

The data for the single-family residential land use category in our study include single-family residential, mobile homes and trailer parks, and rural residential use. The data for the multifamily residential category include various types of multifamily land use that include duplexes, triplexes, townhouses, apartments, and condominiums. The mixed-use category includes areas with a mixture of residential and commercial use. The commercial land use category includes various commercial services, such as retail stores, commercial storage, commercial recreation, and hotels, as well as a mixture of commercial and industrial use, such as business parks. The industrial land use category includes light and heavy industrial use, extraction, wholesaling, and warehousing. The open space category includes "developed open areas within urban settings, and urban and non-urban open areas developed for recreational activities" (SCAG, n.d.b). The institutional and public facility land use category comprises various public facilities, including special-use facilities, educational institutions, military installations, and transportation and utility facilities. The land use category we identified as "other" combines agricultural use, open-water bodies, vacant areas that do not contain agriculture, waterbody and manmade structures, protected or undevelopable areas with "slopes greater than 15 degrees, designated endangered species and plants, wetlands, flood ways, natural habitat" (SCAG, n.d.b) with strong restrictions that prohibit development, and unknown areas without any available land use information.

Next, we calculated the percentage share of each land use category to determine the land use portfolio of cities for 2016 and calculated the percentage change from 2008 and 2016 for each major land use category. We verified our findings of land use change in cities in two ways. In most cases, we checked the cities' official general plan land use maps and zoning maps to confirm the land use designations. In a few cases, when we could not verify our findings of land

use change from cities' official maps, we sent email queries to city planners in which we asked them to verify our findings. We attached a figure of land use change in the city to the email, which identified all of the areas with land use changes from 2008 to 2016, similar to Figure A1, and requested that city planners verify our findings. In a few cases, the changes in land use that we determined from SCAG's data were different from the changes in land use that we determined from the cities' general plan land use maps and zoning maps. In those cases, we used the land use classification used in the zoning regulations of cities to determine the land use changes. As an example, in a number of cities, the land use classification of some parcels identified by SCAG as "1140 Mixed Residential" was different from their land use classification in the city's zoning regulations. In those cases, we relied on the land use classification used in the zoning regulations of cities: We classified them as single-family residential if the specific city categorized the land use or the area as a single-family residential zone (R1) or as multifamily residential use if the city categorized the area as multifamily residential or residential that included R2 zones. We also calculated the regional average of the percentage of residential land use devoted to multifamily housing (24.31%) in each city, which includes the regional average of the percentage of residential land use devoted to multifamily and mixed-use residential land use.

Figure A1. City of Artesia (CA) highlighting land use changes in the city from 2008 to 2016. The parcels highlighted in color show land use change from 2008 to 2016. The major land use changes are from multifamily residential and commercial, to mixed residential and commercial land use, and from industrial to mixed industrial and commercial land use.
Data Source: SCAG; figure by Xinran Wang, used with permission.

As discussed above, the land use data from SCAG do not support a comparison of different types of multifamily land uses across 2008 and 2016 because the SCAG data for 2008 do not differentiate between different types of multifamily land uses. Given this, we examined the correlation between the share of multifamily residential land use, which accommodates all types of multifamily housing, ranging from duplexes to apartments in a city, as well as the net housing density of the city to affirm the soundness of our method and the significance of our findings. We did not include the share of the mixed-use category that accommodates a mixture of commercial and residential land use to examine the correlation between the share of multifamily

residential land use and the net housing density. As Figure A2 shows, there is a strong correlation between the share of multifamily residential land use and net housing density of cities (correlation coefficient = 0.77).

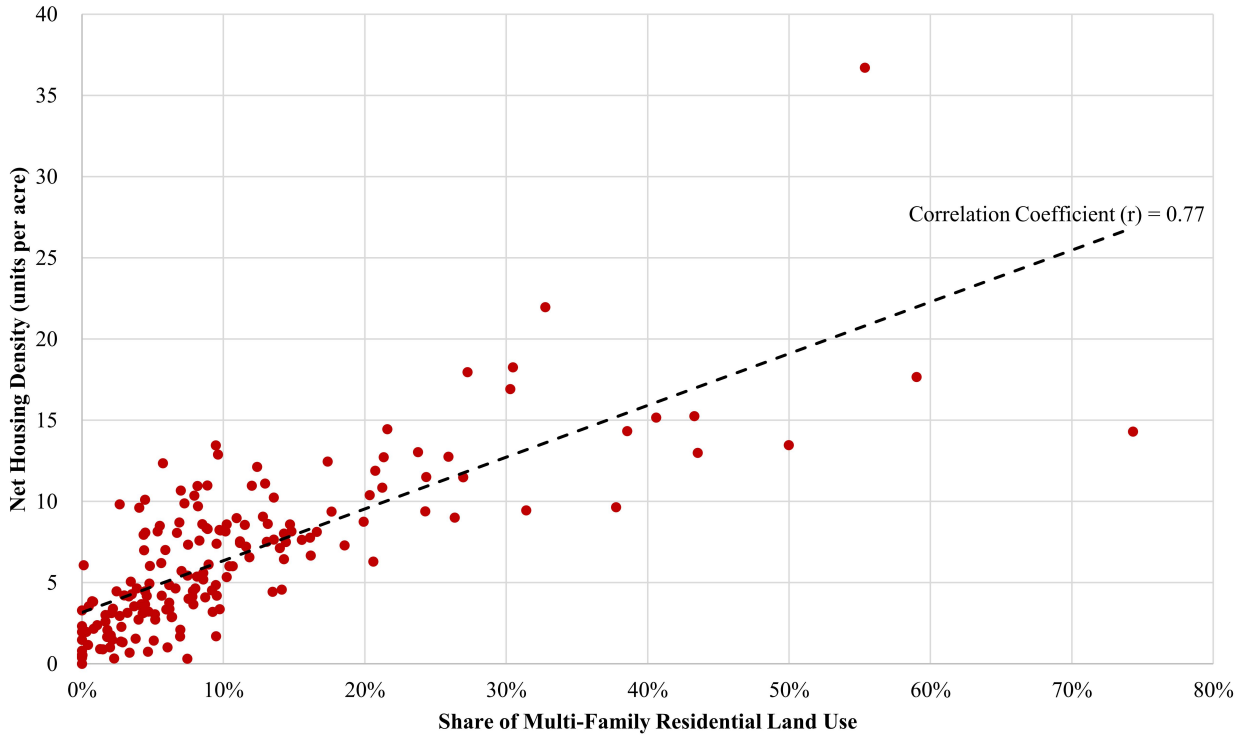

Figure A2. The correlation between the share of multifamily residential land uses of cities in 2016 and their net housing density, which is measured as the number of dwelling units per acre of a city's residential area.
Data Source: SCAG; American Community Survey.

Under California's accessory dwelling unit (ADU) law, a structure with two or more attached units on a single lot is considered a multifamily structure, and, as such, up to four detached dwelling units (2 primary units and 2 ADUs) are permitted on a lot that is classified as a duplex in zoning regulations if certain conditions are met (State of California, 2019, 2020). ADUs are not considered additional units and do not count toward permitted density under the general plan and zoning regulations; however, jurisdictions can use ADU sites to satisfy their regional housing needs.

We used each socioeconomic variable (included in Tables 1 and 2) with an 8-year span to be consistent with the land use data from 2008 to 2016 and to examine the change in these variables by city. We used data for the total population of cities, population below poverty level, racial/ethnic composition, median household income, and total housing units available from the American Community Survey 2006–2010 5-year estimates and 2014–2018 5-year estimates. Based on the land use data and the total housing unit data, we calculated the net housing density for each city as the number of dwelling units per acre of its residential area. We used the Zillow Home Value Index for all types of homes and calculated the average Zillow Home Value Index from January 2006 to December 2010 and from January 2014 to December 2018 to calculate the median home value in each city to be consistent with the American Community Survey 5-year estimates data (Zillow Research, 2019).

Details of the Cluster Analysis

We used land use portfolios of all 180 cities in the five-county Southern California region for our cluster analysis. The clusters are based on cities' land use profiles only. We considered three different clustering methods, including K-means clustering, K-medoids clustering, and agglomerative clustering, using the complete linkage method. Moreover, we conducted each cluster analysis, specifying different numbers of clusters (8, 9, and 10) to determine the optimal number of clusters that captures the key differences in land use profiles of cities. Among the three clustering approaches, the K-medoids approach is not easily influenced by outliers and generates stable clusters that have more explanatory power. Given this, in our study, we used the findings from the K-medoids clustering method with the specification of eight clusters based on eight variables (that is, 8 different types of land use) to develop a typology of cities. The K-

medoids method also is the most effective clustering method based on the minimum possible number of variables and clusters that captures the essential differences in the land use portfolios of cities in the region. Table A1 shows the cluster membership of cities in eight clusters.

Table A1. Cluster membership of the eight clusters of cities in Southern California.

Cluster name	Cluster member city (county)
Exclusive cities	Avalon (LA); Hidden Hills (LA); Rolling Hills (LA); San Marino (LA); Walnut (LA); Villa Park (OC); Wildomar (RC); Twentynine Palms (SB)
Low-density single-family cities	Arcadia (LA); Beverly Hills (LA); Bradbury (LA); Diamond Bar (LA); La Canada Flintridge (LA); La Habra Heights (LA); La Puente (LA); La Verne (LA); Lakewood (LA); Lomita (LA); Malibu (LA); Manhattan Beach (LA); Palos Verdes Estates (LA); Rancho Palos Verdes (LA); Rolling Hills Estates (LA); Sierra Madre (LA); South Pasadena (LA); Temple City (LA); West Covina (LA); Whittier (LA); Mission Viejo (OC); Yorba Linda (OC); Banning (RC); Calimesa (RC); Desert Hot Springs (RC); Indio (RC); Menifee (RC); Moreno Valley (RC); Norco (RC); Palm Desert (RC); Riverside (RC); Big Bear Lake (SB); Hesperia (SB); Loma Linda (SB); Yucaipa (SB)
High-density single-family cities	Artesia (LA); Baldwin Park (LA); Cerritos (LA); Compton (LA); Covina (LA); La Mirada (LA); Lancaster (LA); Norwalk (LA); Palmdale (LA); Pico Rivera (LA); San Fernando (LA); South Gate (LA); Torrance (LA); Fullerton (OC); Garden Grove (OC); La Palma (OC); Placentia (OC); Santa Ana (OC); Hemet (RC); Adelanto (SB); Fontana (SB); Grand Terrace (SB); Ontario (SB); Rancho Cucamonga (SB); Rialto (SB); San Bernardino (SB); Upland (SB); Victorville (SB); Ojai (VC)
Mixed cities	Agoura Hills (LA); Alhambra (LA); Bellflower (LA); Burbank (LA); Calabasas (LA); Downey (LA); Hermosa Beach (LA); Long Beach (LA); Los Angeles (LA); Lynwood (LA); Montebello (LA); Monterey Park (LA); Pasadena (LA); Pomona (LA); Rosemead (LA); San Gabriel (LA); Santa Clarita (LA); Anaheim (OC); Brea (OC); Buena Park (OC); Cypress (OC); Dana Point (OC); Fountain Valley (OC); Huntington Beach (OC); La Habra (OC); Laguna Beach (OC); Laguna Hills (OC); Orange (OC); Tustin (OC); Westminster (OC); Blythe (RC); Cathedral City (RC); Coachella (RC); Corona (RC); La Quinta (RC); Lake Elsinore (RC); Murrieta (RC); Perris (RC); San Jacinto (RC); Barstow (SB); Colton (SB); Montclair (SB); Needles (SB); Redlands (SB); Camarillo (VC); Fillmore (VC); Oxnard (VC); San Buenaventura (VC); Santa Paula (VC)
Low-density green cities	Azusa (LA); Claremont (LA); Duarte (LA); Glendale (LA); Glendora (LA); Monrovia (LA); San Dimas (LA); Westlake Village (LA); Aliso Viejo (OC); Irvine (OC); Laguna Niguel (OC); Lake Forest (OC); Newport Beach (OC); Rancho Santa Margarita (OC); San Clemente (OC); San Juan Capistrano (OC); Beaumont (RC); Canyon Lake (RC); Indian Wells (RC); Palm Springs (RC); Rancho Mirage (RC); Temecula (RC); Chino (SB); Chino Hills (SB); Highland (SB); Moorpark (VC); Simi Valley (VC); Thousand Oaks (VC)
High-density Multifamily cities	Bell (LA); Bell Gardens (LA); Cudahy (LA); Culver City (LA); El Monte (LA); Gardena (LA); Hawaiian Gardens (LA); Hawthorne (LA); Huntington Park (LA); Inglewood (LA); Lawndale (LA); Maywood (LA); Paramount (LA); Redondo Beach (LA); Santa Monica (LA); Signal Hill (LA); West Hollywood (LA); Costa Mesa (OC); Laguna Woods (OC); Stanton (OC)
Military cities	Los Alamitos (OC); Seal Beach (OC); Port Hueneme (VC)
Industrial cities	Carson (LA); Commerce (LA); El Segundo (LA); Industry (LA); Irwindale (LA); Santa Fe Springs (LA); South El Monte (LA); Vernon (LA)

Notes: Clusters are based only on cities' 2016 land-use profiles. LA = Los Angeles County; OC = Orange County; RC = Riverside County; SB = San Bernardino County; VC = Ventura County.
Data Source: Southern California Association of Governments.

Details of the Statistical Analysis

Table A2 presents the results of one-way analysis of variance (ANOVA) tests, which indicate statistically significant differences in the socioeconomic characteristics across the eight clusters of cities as well as the *change* in their socioeconomic characteristics. We found statistically significant differences in the racial/ethnic composition, share of population below poverty level, median household income, median home value, population density, net housing

density, and age of city across clusters of cities. These findings indicate that the cities' land use profiles are associated with their socioeconomic characteristics. Further, the differences in the *change* in key socioeconomic characteristics across clusters of cities, including the share of non-Hispanic Whites, share of population below poverty level, median household income, median home value, population density, and net housing density, were statistically significant. Moreover, we found statistically insignificant differences in the fifth-cycle and sixth-cycle regional housing needs allocation for low- and very-low-income households and households of all incomes as well as the *change* of regional housing needs allocations across clusters of cities, indicating that the old and new regional housing needs allocation methods adopted by SCAG do not take pre-established region-wide land use inequities into consideration.

Table A2. Results of the one-way analysis of variance of selected variables for the eight clusters of cities in Southern California.

	Variable	*F*(7,172)	η2	*p*
Socioeconomic characteristics	Non-Hispanic Whites (%)	8.15	0.2490	0.0000
	African Americans (%)	2.38	0.0884	0.0238
	Asians (%)	0.86	0.0340	0.5360
	White Hispanics (%)	5.32	0.1780	0.0000
	Non-White Hispanics (%)	4.45	0.1533	0.0001
	Other Races (%)	1.54	0.0591	0.1555
	Population Below Poverty (%)	4.75	0.1621	0.0001
	Median Household Income ($)	8.24	0.2512	0.0000
	Median Home Value ($)	4.57	0.1570	0.0001
	Population Density (per acre)	21.52	0.4669	0.0000
	Net Housing Density (units per acre)	21.10	0.4620	0.0000
	Age of Cities in Cluster	2.81	0.1027	0.0085
RHNA allocation	5th Cycle Very Low-Income & Low-Income RHNA Allocation	0.77	0.0302	0.6170
	5th Cycle Total RHNA Allocation	0.78	0.0307	0.6062
	6th Cycle Very Low-Income & Low-Income RHNA Allocation	0.54	0.0214	0.8061
	6th Cycle Total RHNA Allocation	0.55	0.0219	0.7949
Change of land use characteristics	Single-Family Residential % Change	0.54	0.0213	0.8064
	Multi-Family Residential % Change	0.18	0.0074	0.9887
	Mixed-Use % Change	1.97	0.0742	0.0619
	Commercial % Change	1.70	0.0648	0.1116
	Industrial % Change	1.50	0.0574	0.1716
	Open Space % Change	0.73	0.0287	0.6504
	Institutional & Public Facility % Change	1.08	0.0419	0.3814
	Other % Change	1.71	0.0652	0.1085
Change of socioeconomic characteristics	Non-Hispanic Whites % Change	3.49	0.1243	0.0016
	African Americans % Change	1.61	0.0615	0.1350
	Asians % Change	1.45	0.0556	0.1900
	White Hispanics % Change	0.70	0.0277	0.6710
	Non-White Hispanics % Change	0.92	0.0359	0.4961
	Other Races % Change	1.73	0.0658	0.1044
	Population Below Poverty % Change	2.35	0.0873	0.0257
	Median Household Income ($) Change	3.66	0.1295	0.0011
	Median Home Value ($) Change	3.80	0.1339	0.0007
	Population Density (per acre) Change	2.59	0.0954	0.0145
	Net Housing Density (units per acre) Change	6.86	0.2183	0.0000
Change of RHNA allocation	Very Low-Income & Low-Income RHNA Allocation Change	0.49	0.0196	0.8406
	Total RHNA Allocation Change	0.51	0.0202	0.8297

Notes: The mixed-use category includes residential and commercial use; commercial land use includes both commercial use and mixed commercial and industrial uses; the land-use category identified as other includes water, protected or undevelopable, agricultural, vacant, and unknown uses; RHNA = Regional Housing Needs Assessment; RHNA allocation change represents the change of allocated housing units for each jurisdiction from the 5th cycle RHNA Allocation Plan to the 6th cycle RHNA Plan; The independent variable for all the ANOVA tests is the clusters of cities based on land-use profiles of cities, and the dependent variables are listed in the second column in the table.

Data Source: SCAG; Zillow Research; American Community Survey.

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