PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

Making the Most of Transit

Density, Employment Growth, and Ridership around New Stations

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Jed Kolko
with research support from Marisol Cuellar Mejia, Davin Reed, and Eric Schiff

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# Summary

In 2008 California adopted Senate Bill (SB) 375, which requires the integration of land use and transportation planning to reduce greenhouse gas emissions from vehicle miles traveled (VMT). A prime example of such activities is transit-oriented development (TOD), the targeting of residential, commercial, or mixed-used development to areas around transit stations.

This paper assesses how well California has achieved the integration of land use and transportation planning by looking at employment growth around new transit stations from 1996 to 2006. Three facts, presented in the paper, underscore the importance of locating transit near jobs and encouraging job growth near transit:

- Transit ridership depends on proximity to transit, especially workplace proximity.
- Employment density is more strongly associated with transit ridership than residential density is.
- In California, residential density is higher than the national average and rising, but employment density is lower than the national average and falling.

Because employment patterns are at least as important for transit ridership as residential patterns are, and because employment patterns and commercial land use have received much less emphasis in policy work and the research literature, the analysis in this paper focuses on employment growth.

Looking across the 200-plus transit stations that opened in California from 1992 to 2006, we find that these new stations were located in areas with high residential density and very high employment density. Yet the opening of new stations was not accompanied by an increase in average employment growth in the areas immediately surrounding these stations (relative to comparison areas), either when the stations opened or several years afterward. What's more, employment around new stations varied widely: Employment growth increased near 18 new stations and decreased near 20, relative to comparison areas, with the largest increases in areas that had higher residential and employment density prior to the station opening. For the rest of the stations, the difference between employment growth around the station and in the comparison areas before and after the station opening was not statistically significant. Employment growth increased most around stations located in higher-density areas.

In short, we find an absence of any boost to employment growth associated with the opening of new transit stations, on average. This finding runs counter to a goal of transit-oriented development policy and suggests that California has missed an opportunity to get the maximum increase in transit ridership and reduction in VMT from its recent transit investments. Existing zoning patterns and fiscal incentives, though favoring commercial over residential development, have not resulted in employment growth around new transit stations. Furthermore, most TOD policies—including the TOD strategy in SB 375—discourage commercial development relative to residential development near transit. But if California is to make the most of its transit investments, land use and transportation planning must do more to boost employment growth around transit stations.

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Introduction

California has, for years, sought to tie its transportation planning to land use policy in order to balance economic growth, mobility, air quality, habitat preservation, and other goals (Barbour and Teitz 2006). In 2008, California adopted Senate Bill (SB) 375, which furthers the integration of land use and transportation planning in order to reduce greenhouse gas (GHG) emissions. As SB 375 requires, the California Air Resources Board established targets in 2010 for each of the state's 18 metropolitan planning organizations (MPOs), which, in collaboration with cities and counties, are required to integrate land use planning into the regional transportation planning process.

The emission-reduction targets will partly be met through a variety of policies designed to reduce vehicle miles travelled (VMT), including land use, pricing, and investments in transit and other alternatives to driving alone. Other policies, such as fuel standards, are also being used to reduce GHG emissions from the transportation sector, and California is trying to reduce emissions from other sectors as well (Bedsworth, Hanak, and Kolko 2011). Transportation models and previous research support this approach, demonstrating that integrated strategies that include, for instance, transit investments coordinated with zoning changes and parking policies, result in greater VMT reduction than policies undertaken singly.

A prime example of integrating land use and transportation planning for the purpose of VMT reduction is transit-oriented development (TOD), which aims to create compact, dense, urban spaces around transit stations through residential, commercial, or mixed-used development, supported by appropriate urban design and policies. Because transit-oriented development has the potential to shift residents and workers closer to transit, TOD has the potential to reduce VMT by raising transit ridership. New transit investments can raise the share of residents and workers close to transit in two ways: (1) by locating transit in high-density areas, and (2) by encouraging greater density around new transit stations.

Locating transit in high-density areas depends, of course, on the existence of high-density areas in the first place. Only the larger metropolitan areas with high-density neighborhoods can support fixed-line transit such as subways, rail, or streetcars, because density provides the ridership needed to make such systems economically feasible. The existence of high-density areas that are good candidates for transit stations is the result of cumulative public policy and private sector decisions and topographic constraints. This paper will demonstrate that transit ridership at the metropolitan level is indeed higher where the average density of the metropolitan area is higher, and that employment density is more strongly associated with transit ridership than residential density is. Looking at California's recent history, this paper also shows that new transit stations have been located in areas of relatively high density, though not as high as the areas around older transit stations.

Increasing density around new transit stations depends on both public- and private-sector decisions that encourage or discourage development, including zoning, urban design, and investment decisions. Even if the land around a new transit station becomes more valuable because of its increased accessibility, higher values result in new development and higher density only if local policies facilitate, or at least allow, development. Patterns of development around new transit nodes affect the extent to which transit investments lead to greater transit ridership and therefore the reduction of VMT and the achievement of SB 375 goals.

In recent years, California has invested considerably in fixed-line transit, with over 200 new transit stations opening in the state between 1992 and 2006, in both existing and new systems. Much more transit investment is planned for the future. The contribution of these investments to VMT reduction will depend, in part, on how well these investments are integrated with land use planning and with existing transportation infrastructure.

This paper assesses how well this integration has been achieved in California in the period from 1992 to 2006, answering the following two questions in depth:

1. To what extent were new transit nodes in California located in areas with high residential or employment density?
2. How much have residential and, especially, employment densities increased around new transit nodes?

We focus on fixed-line transit, such as subways and light rail, because it represents a large share of transit investment. Fixed-line transit is also perceived to have the greatest potential for integration with land use planning (Bedsworth, Hanak, and Stryjewski 2011). Our focus is metropolitan and commuter transit—not inter-regional transit like high-speed rail—consistent with SB 375's emphasis on integrated planning at the regional level.

This paper proceeds as follows. First, we provide a brief overview of land use patterns and transit trends, highlighting the most relevant findings for our analysis of integrating land development with transit investments. Two important facts stand out in each area:

Land use trends. Employment density in California is lower than the national average and falling, even though residential density is higher in California than the national average and rising.

Transit trends. Transit ridership falls sharply as distances from transit stations increase. This trend is even more pronounced for distances from workplaces than for distances from residences.

Next, the paper reviews research on land use and transportation, which concludes that employment land use patterns have at least as strong a relationship with transportation behaviors as residential land use patterns do.

Together, these sections provide the context for the paper's two main research questions: Where did new transit stations open, and did residential and employment growth accompany those new stations? Our findings to these questions, along with results reported from previous studies, point to challenges and opportunities for reducing VMT in California.

In Brief: Land Use Trends

This section describes land use patterns and recent trends in the U.S. and California. Land use patterns are the cumulative result of decisions made over many years by governments, businesses, and households. Because buildings and infrastructure can last for decades or centuries, land use patterns change slowly except in rapidly growing areas with new development. Existing land use patterns can support or constrain transportation policy options.

Describing land use: Density and centralization

Density and centralization are two important measures of land use patterns. Put very simply, density reflects how tightly packed together people (or housing or jobs) are within a given land area, and centralization reflects the clustering of people (or housing or jobs) near the center of a city or metropolitan area. Decentralized land use tends to have lower density: the density of both population and employment typically declines with increasing distance from downtown. "Sprawl" often refers to land use that is both low-density and decentralized (Glaeser and Kahn 2004). But decentralization does not always imply low-density: a metropolitan area could be both decentralized and high-density if, for instance, it includes large, dense centers of employment outside of traditional downtowns. Although density is just one of many measures of land use patterns, the research literature suggests it is highly relevant for transit ridership and often closely related to other measures of land use patterns.

Density and centralization have the advantage of being relatively easy to quantify using widely available data, which facilitates comparisons across geographic areas at many levels (Census tracts, counties, metropolitan areas) and over time. Other measures of land use patterns include whether land is developed in a continuous or "broken" fashion; whether there are few or many sub-centers of employment outside of downtown; and whether different land uses, like residential and commercial, tend to be mixed or separated.*

The discussion of land use and transportation in this paper mentions the "jobs-housing balance." This is one important measure of the mixing or separation of different land uses.

* Galster et al. (2001) defines a variety of land use measures and demonstrates that many are uncorrelated with each other. Lang and LeFurgy (2003) and Redfearn (2007) examine employment concentrations outside of traditional downtowns.

Trends in Decentralization

For many decades, American cities have become less dense and more decentralized. Nationwide, urban population densities peaked in 1950, fell sharply between 1950 and 1990, and remained relatively constant between 1990 and 2000. Population has steadily decentralized since 1890 as suburbs have grown and the differences in density between higher-density cities and lower-density suburbs have narrowed (Kim 2007). Although employment is more concentrated near downtowns than are housing and population, only 21 percent of employment in large metropolitan areas is within three miles of downtown.[1]

[1] I use "downtown," "city center," and "Central Business District" interchangeably throughout this report.

Despite these general trends in density and decentralization, metropolitan areas vary widely. In California, employment is more concentrated near the central business district (CBD) in San Francisco-Oakland (21 percent of metro employment within three miles) and Sacramento (22 percent) than in Los Angeles (7 percent) or San Diego (12 percent).[2] And although nearly all metro areas experienced further decentralization of employment between 1992 and 2006, this movement of jobs away from downtowns was more pronounced in some metros, such as Los Angeles and San Francisco-Oakland, than others, such as San Jose and Sacramento.

Explanations for increasing decentralization and declining densities fall into two categories: "natural evolution theory" and "fiscal-social problems" (Mieszkowski and Mills 1993; Nechyba and Walsh 2004). Under "natural evolution theory," households consider both the cost of commuting to downtown jobs, which rises with increasing distance from the city center, and the cost of housing, which falls with increasing distance from the city center. Decentralization can result from either improved transportation technology that lowers the cost of commuting (e.g. cars replacing horse-drawn carriages, or the building of better roads) or greater demand for housing. The "fiscal-social" explanation is that lower-density suburbs grow as people move out of cities with bad public schools, high crime, and worse public services.[3] Although, as Mieszkowski and Mills (1993) point out, these two broad explanations are related and hard to disentangle, the evidence leans more in favor of the "natural evolution" explanation. Glaeser and Kahn (2004) show that decentralization occurred even in metropolitan areas with lower central-city poverty, and Baum-Snow (2007) shows that the development of the interstate highway system in the 1950s and 1960s, which made commuting long distances into downtown easier, contributed significantly to sprawl.

These explanations for decentralization describe household behavior and either ignore business location decisions (fiscal-social problems) or assume businesses remain at the city center (natural evolution theory). Yet jobs, too, have decentralized to lower-density areas. People follow jobs to reduce their commutes, and jobs follow people to attract customers and workers (Kolko 2009). Extensive research has examined the effects of these trends on transportation behaviors and on other economic and social outcomes such as employment prospects, business productivity, workers' skills acquisition, obesity, and public health.

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[2] The central business district of a metropolitan area can be defined in multiple ways. Both Kneebone (2009) and this paper rely on a list of CBD Census tracts from the 1982 Census of Retail and consider the CBD as the center of economic activity in a metropolitan area. Place names refer to metropolitan areas.

[3] "Natural evolution theory" is rooted in the monocentric city model, presented in Brueckner (1987); the "fiscal-social problems" explanation is based on the Tiebout (1956) model of residential sorting into jurisdictions.

Research approach

This analysis uses data from several sources: population from the decennial Census, housing from the decennial Census and the United States Postal Service (USPS), transportation behaviors from the Census Transportation Planning Package (CTPP), and employment from the National Establishment Time-Series (NETS) database. We present findings at the state, metropolitan area, Census tract, or Census blockgroup level. Metropolitan areas consist of one or more counties, counties are divided into Census tracts, and Census tracts are divided into blockgroups and then blocks. Census tracts are defined to represent a neighborhood and have, on average, 4,000 inhabitants; the typical blockgroup has 1,500 inhabitants.

The decennial Census reports population and occupied housing unit counts and land area at the blockgroup (and block) level.* CTPP transportation data are based on the 2000 Census and report commuting mode (drive alone, carpool, subway, bus, etc.) by place of residence and place of work at the tract and blockgroup level.

The NETS database is a national longitudinal microdata panel of the businesses in the Dun & Bradstreet business register. The NETS provides employment levels, detailed industry, and exact street address for more than 200 million establishment-year observations. The NETS records used here cover 1992–2006. No publicly available dataset approaches the comprehensiveness and geographic detail of the NETS. By geocoding the NETS, we generate employment totals by year by Census tract and blockgroup.**

* The latest decennial Census data are from 2000, and the follow-on American Community Survey (ACS) data do not yet report population or other variables at detailed levels of geography like Census tracts or blocks. Instead, we use tract-level data from 2008 on occupied housing units from USPS, which reports the number of addresses, active and vacant, residential and commercial, to the U.S. Housing and Urban Development Department (HUD). To our knowledge, these USPS/HUD housing unit data are the only nationally available tract-level data that show residential patterns after 2000.

** Nationally, 94 percent of employment was in establishments that geocoded successfully, with higher shares in urban areas. We omitted un-geocoded establishments from the blockgroup totals. We imputed Census tract location for un-geocoded establishments by matching reported ZIP code to Census ZIP Code Tabulation Area (ZCTA) and then allocating that employment to tracts.

Residential and Employment Density Patterns

Despite popular conceptions that California—particularly Southern California—is the epitome of sprawl development, residential density in California is well above the national average. In Table 1 we report weighted density measures, which are unaffected by the inclusion of undeveloped land within a metropolitan or state boundary.

Population density in California in 2000 was 49 percent higher than the national average.[4] California's population density increased from 1990 to 2000, even though national residential density was unchanged. Although tract-level data on population since 2000 are unavailable, housing unit density—also weighted—continued its slight upward trend from 2000 to 2008, both in absolute terms and relative to the national trend.

[4] Because we report weighted density, this means that the typical person in California lives in a Census tract that is 49% more dense than the typical person in the U.S. overall.

Measuring density

Conventional density is measured as the number of people (or housing units or workers) per square kilometer (or other measure of area). But metropolitan areas and states often include undeveloped or sparsely developed land, so conventional density measures can understate the density of the settled areas where people actually live and work.

Weighted density helps to account for this. Weighted density measures the number of people (or housing units or workers) in the areas where people actually live or work and therefore better reflect the land use patterns experienced by a typical person or worker.

Weighted population density for a metropolitan area is the weighted average of Census tract population density (tract population divided by tract land area) for all tracts in the metropolitan area, where the weight is the tract's share of metropolitan population. Tracts without population receive a weight of zero and therefore do not affect the weighted density of the metropolitan area (Glaeser and Kahn 2004). In effect, the weighted-density measure equals the tract density for the average person within a metropolitan area; we use the same method to calculate housing and employment density.

Because tracts with more population (or housing or employment) tend to have higher density, tract-weighted density measures for metropolitan areas tend to be higher than unweighted density measures. An alternative method for excluding undeveloped land is "net density": population (or employment) divided by land area excluding farmland, public lands, and other undeveloped areas (Galster et al. 2001). Net density requires detailed data on land uses in order to identify and exclude undeveloped land, whereas weighted density requires only on tract population (or employment) and land area.

To understand how weighted density measures work, consider two hypothetical cities, Sparseville and Densetown. Each has a population of 1,000 residents and consists of two one-square mile Census tracts. In Sparseville, 500 people live in each tract, whereas in Densetown, all 1,000 residents live in one tract and the other is undeveloped. Both Sparseville and Densetown have a conventional density of 500 people per square mile (1,000 residents divided by 2 square miles). But the weighted density measure is 500 people per square mile in Sparseville, since the average person lives in a tract with 500 people per square mile, while the weighted density measure in Densetown is 1,000 people per square mile, since the average person (in fact, all people) lives in a tract with 1,000 people per square mile.

Throughout this report, we report weighted density measures for metropolitan areas and states.

California's employment density is quite different than its population density. Employment density in California is lower than in the U.S. overall and—like the national trend—is falling.[5] In 2006, employment density was 15 percent below the U.S. average. Employment densities have fallen most sharply near downtown areas: In the six largest California metropolitan areas, employment densities within three miles of

[5] In general, employment density is higher than residential density: the employment density of the typical worker's Census tract is much higher than the residential density of the typical resident's Census tract, in part because people are more likely to work than live in areas like downtowns where both residential and employment density are high.

downtown fell nearly 25 percent between 1992 and 2006. Employment densities ten miles or more from downtown rose slightly over the same period.

TABLE 1
Residential and employment density in California and the U.S. (persons, housing units, or workers per square kilometer)

	California	U.S.	Ratio
Population density			
1990	3073	2171	1.42
2000	3230	2171	1.49
Occupied housing unit density			
1990	1154	924	1.25
2000	1179	890	1.32
2008	1197	887	1.35
Employment density			
1992	7351	8995	0.82
2000	7088	8575	0.83
2006	5632	6645	0.85

NOTE: Density is reported as residents, houses, or workers per square kilometer. Tract density weighted by tract population, housing, or employment as appropriate, as explained in text. Intuitively, this equals the tract-level density for the average person, housing unit, or employee in the metropolitan area.

In general, both residential and employment density are higher in larger metropolitan areas. Table 2 shows how California's 12 largest metropolitan areas rank among the nation's metropolitan areas according to population, residential density, and employment density. Although metropolitan area population is generally closely correlated with employment and, especially, residential density, these large California metro areas display considerable variation in density.

TABLE 2
National residential and employment density rankings for large California metropolitan areas, 2000

Metro	Population	Residential density	Employment density
Los Angeles-Long Beach-Santa Ana	2	2	23
San Francisco-Oakland-Fremont	12	3	3
Riverside-San Bernardino-Ontario	13	47	236
San Diego-Carlsbad-San Marcos	17	9	35
Sacramento-Arden-Arcade-Roseville	27	30	24
San Jose-Sunnyvale-Santa Clara	28	6	47
Fresno	58	40	144
Oxnard-Thousand Oaks-Ventura	61	19	212
Bakersfield	70	54	271
Stockton	82	21	209
Santa Rosa-Petaluma	98	89	206
Modesto	100	36	233

Note: Population data from Census; employment data from NETS. Each metropolitan area comprises one or more counties, following the 2008 Core Based Statistical Area definitions, as follows. Los Angeles-Long Beach-Santa Ana: Los Angeles and Orange Counties. San Francisco-Oakland-Fremont: San Francisco, Marin, San Mateo, Alameda, and Contra Costa Counties. Riverside-San Bernardino-Ontario: Riverside and San Bernardino Counties. San Diego-Carlsbad-San Marcos: San Diego County. Sacramento-Arden-Arcade-Roseville: Sacramento, El Dorado, Placer, and Yolo Counties. San Jose-Sunnyvale-Santa Clara: Santa Clara and San Benito Counties. Fresno: Fresno County. Oxnard-Thousand Oaks-Ventura: Ventura County. Bakersfield: Kern County. Stockton: San Joaquin County. Santa Rosa-Petaluma: Sonoma County. Modesto: Stanislaus County.

The Los Angeles metropolitan area ranks second in the nation in residential density, following New York. Yet it ranks only 22nd-highest in employment density. In fact, all but two metro areas—San Francisco and Sacramento—rank lower on employment density than on residential density, and many, including Riverside, Oxnard, and Bakersfield, rank much lower. San Francisco and Sacramento's relatively high employment densities arise, in part, from the prevalence of industries that tend to cluster in traditional downtowns (like finance and government). San Francisco also saw rapid growth in a historical period when development patterns were denser.

The key fact for the analysis, below, is that employment density in California is below the U.S. average and falling. As we will show, lower employment densities are a challenge for supporting transit investments and for integrating land use and transportation planning.

In Brief: Transit and Driving Trends

Mass transit is a key part of California's strategy to reduce traffic congestion, air pollution, and greenhouse gas emissions. Since the early 1980s, transit has accounted for well over a third of all transportation spending in California, with even higher shares in the major metropolitan areas. Most transit capital spending is associated with rail projects, including subways, commuter rail, light-rail, and streetcars (Bedsworth, Hanak, and Kolko 2011). This section reviews trends in transit ridership and its relationship to VMT reduction.

Transit Ridership and Proximity

For the state as a whole, the share of commuters taking transit increased from 5 percent to 5.5 percent between 1990 and 2008—76.4 percent of all commuters still drive alone to work. Nationally, the share of commuters taking transit looked much the same: 5.3 percent in 1990 and 5.2 percent in 2008.

The share of commuters taking transit to work varies by metropolitan area, with the highest transit ridership in higher-density metropolitan areas. The San Francisco area has the second-highest transit ridership in the country, 15.3 percent of commuters, though this is only half the level of New York (Table 3). The next-highest transit use in California occurs in Los Angeles—6.6 percent of commuters, less than half San Francisco's ridership. Other large California metropolitan areas are well below the Los Angeles level, with the Inland Empire (Riverside and San Bernardino counties) having a transit share of just 1.9 percent.

Just as transit ridership varies across metropolitan areas, ridership varies within metropolitan areas. Proximity is an important factor. Transit ridership diminishes rapidly as distances from transit stations increase: one-quarter mile is the limit that most people will walk for most trips (Untermann 1984). Cervero (2007) uses one-half mile as the distance within which residents' transit ridership differs from residents elsewhere on average, though he finds that residents of developments built near transit are more likely to commute by transit even if their workplaces are one mile from transit. Most studies of transportation behaviors reviewed in Arrington and Cervero (2008) and Cervero, Ferrell, and Murphy (2002) use either one-quarter mile or one-half mile as the distance from a station that affects mode choice.

Data from California illustrate how strongly proximity to transit determines ridership—even more for workplace proximity than for residential proximity.[6] Within one-half mile of a transit station, 6.7 percent of residents and 7.2 percent of workers commute by subway, streetcar, or railroad (Table 4). In contrast, beyond one-half mile of a transit station (but still in counties with stations), only 1.1 percent of residents and 0.5 percent of workers commute by subway, streetcar, or railroad. Ridership, therefore, falls quickly at greater distances from transit. Yet even among Californians who live or work *within* half a mile of a transit station, the majority drive alone to work—so proximity to transit hardly guarantees high ridership.

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[6] We measure the distance from Census blockgroups to the nearest transit station (or "node") that was operational prior to 2000, including stations on fixed-line rail, subway, streetcar, and a handful of bus-rapid-transit (BRT) routes, but not standard bus lines. Later in this report we describe these transit stations and their selection in greater detail. Blockgroup-level commute mode data come from the 2000 CTPP.

TABLE 3
Transit ridership among 40 largest U.S. metros, 2008

Metropolitan Area (California metros in bold)	**Share of Commuters Using Transit (%)**
New York-Northern New Jersey-Long Island	31.6
San Francisco-Oakland-Fremont	**15.3**
Washington-Arlington-Alexandria	14.1
Boston-Cambridge-Quincy	12.2
Chicago-Naperville-Joliet	11.8
Philadelphia-Camden-Wilmington	9.6
Seattle-Tacoma-Bellevue	8.4
Baltimore-Towson	6.8
Portland-Vancouver-Beaverton	6.8
Los Angeles-Long Beach-Santa Ana	**6.6**
Pittsburgh	6.0
Denver-Aurora	5.2
Minneapolis-St. Paul-Bloomington	5.0
Cleveland-Elyria-Mentor	4.1
Miami-Fort Lauderdale-Pompano Beach	3.9
Milwaukee-Waukesha-West Allis	3.8
Las Vegas-Paradise	3.8
Atlanta-Sandy Springs-Marietta	3.8
San Jose-Sunnyvale-Santa Clara	**3.8**
San Diego-Carlsbad-San Marcos	**3.6**
Austin-Round Rock	3.2
Sacramento--Arden-Arcade--Roseville	**3.0**
St. Louis	2.8
Providence-New Bedford-Fall River	2.8
Houston-Sugar Land-Baytown	2.7
Phoenix-Mesa-Scottsdale	2.7
Cincinnati-Middletown	2.7
San Antonio	2.7
Charlotte-Gastonia-Concord	2.4
Virginia Beach-Norfolk-Newport News	2.2
Riverside-San Bernardino-Ontario	**1.9**
Detroit-Warren-Livonia	1.9
Columbus	1.8
Dallas-Fort Worth-Arlington	1.7
Orlando-Kissimmee	1.6
Kansas City	1.6
Tampa-St. Petersburg-Clearwater	1.4
Indianapolis-Carmel	1.3
Jacksonville	1.2
Nashville-Davidson--Murfreesboro--Franklin	1.1

NOTE: “transit” includes subway, railroad, bus, ferry, and streetcar. People working from home are excluded. See Table 2 for counties included in California metropolitan areas. Source: American Community Survey, 2008 (1-year estimates).

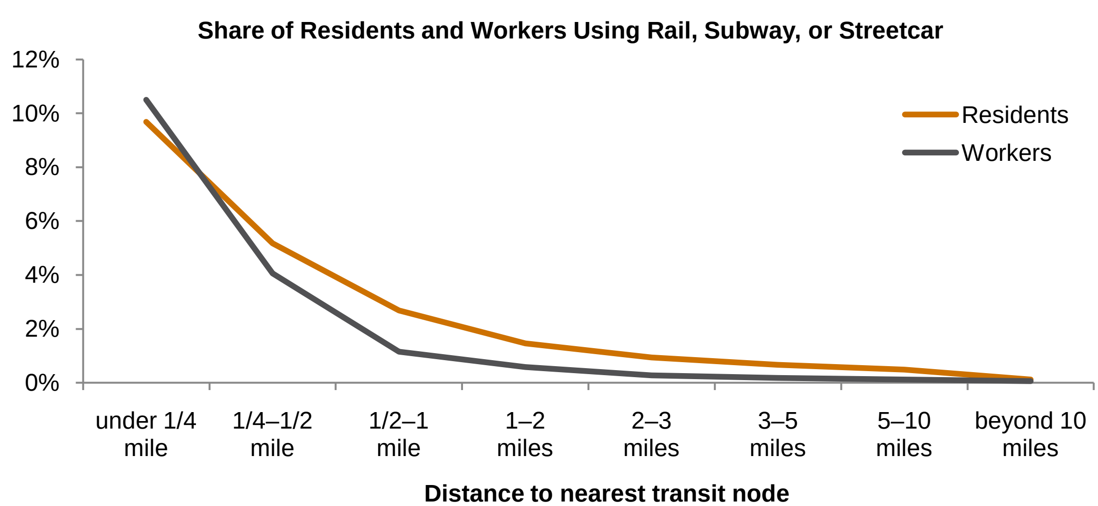
TABLE 4
Commuting mode, by proximity to transit stations, 2000

	Live within 1/2 mile of transit node (%)	Live beyond 1/2 mile of transit node, in county with transit nodes (%)	Live in county without transit nodes (%)	Work within 1/2 mile of transit node (%)	Work beyond 1/2 mile of transit node, in county with transit nodes (%)	Work in county without transit nodes (%)
Subway	4.3	0.7	0.1	5.0	0.2	0.0
Streetcar	1.6	0.1	0.0	0.9	0.1	0.0
Railroad	0.8	0.3	0.0	1.3	0.2	0.0
Bus	13.5	3.8	1.8	10.4	3.4	1.5
Bike	1.7	0.7	1.1	0.9	0.7	1.2
Walk	7.7	2.5	3.2	3.8	2.7	3.3
Carpool	14.0	14.9	16.0	14.1	15.1	15.7
Drive alone	54.6	75.9	76.5	62.0	76.6	77.2
Share of residents or workers	6	74	21	12	68	18

NOTE: 2000 CTPP commuting behavior, relative to nodes operational 1999 or earlier. Columns 1, 2, 4, 5 include only counties with transit nodes: Alameda, Contra Costa, Los Angeles, Orange, Riverside, Sacramento, San Bernardino, San Diego, San Francisco, San Joaquin, San Mateo, Santa Clara, and Ventura. Other modes—ferry, motorcycle, taxi, and "other"—account for 1 percent of commutes. Excludes people working at home (3.8 percent of all California workers). Respondents who used mixed modes (e.g., bus plus rail or some form of transit plus driving) are asked to choose the principal mode, based on the longest distance traveled.

In fact, fixed-line transit ridership falls considerably at distances beyond just one-quarter mile of a transit station. Looking only at the share of commuters using subway, streetcar, or railroad, the likelihood of using transit falls by approximately half when comparing residents or workers within one-quarter mile of a transit station and those between one-quarter and one-half mile of a transit station (Figure 1). As distance from a transit station increases, the likelihood of using transit fall dramatically for both residents and workers—but especially for workers. Transit ridership for workers within one-quarter mile of a station is slightly higher (10.5 percent versus 9.7 percent) than for residents within the same distance, but, for each interval beyond one-half mile of a station, transit ridership is at least twice as high for residents as for workers.

FIGURE 1
Transit ridership decreases as distance from transit stations increases



NOTE: Commute mode data from the 2000 CTPP. Distance measured as straight-line distance from the centroid of the blockgroup of residence or workplace to the nearest transit station operational as of 2000.

Even among those who live near transit stations, ridership varies: 45 percent of Pleasant Hill BART TOD's residents commuted via transit, compared to only 3 percent of the LA Metro Long Beach TOD's residents (Lund et al. 2004). Workers' transit ridership was sensitive to workplace distance from the transit station. But residents' transit ridership was not sensitive to residential distance from the transit station.[7] Transit ridership also depended on transit quality, including travel time and frequency of feeder bus services, as well as the availability and cost of workplace parking (Lund et al. 2004). Much of the relationship between household proximity to transit and transit ridership is self-selection: people who want to commute by transit choose to live near transit. Relaxing zoning regulations or other barriers to mobility would facilitate this self-selection and raise transit ridership (Cervero 2007).

Does Transit Investment Reduce VMT?

Transit investment and even transit ridership do not necessarily lead to VMT reduction. Even though transit availability is associated with higher transit ridership for nearby residents and workers, the effect of transit investment on VMT depends on numerous factors, some of which become apparent only after looking across multiple metropolitan areas that have experienced different rates of growth in public transit infrastructure.

Although transit's share of commuting rose in California from 1990 to 2008, VMT per capita rose as well, by 3.5 percent (this was less than the national increase of 13.7 percent). Among California's large metropolitan areas, those where transit share increased saw no greater reduction (or slower growth) in VMT per capita.[8] Three possible reasons help explain this.

First: Rail investments tend not to increase overall transit ridership in most cities; rather, most rail transit commuters are former bus commuters, not former drivers, and the main effect of rail investment may be giving transit users a faster transit option rather than reducing VMT and associated emissions (Baum-Snow and Kahn 2005). Changes in commuting patterns support this claim for the nation overall but not for California. In the country as a whole, from 1990 to 2008, the share of fixed-line transit commutes (rail, subway, and streetcar) rose by 0.21 percent while the share of other transit commutes (primarily bus) fell by 0.26 percent. In California, the fixed-line transit share rose by 0.57 percent while other transit share fell by just 0.07 percent. The increase in California's fixed-line transit share was almost entirely a net increase in overall transit ridership.

Second: The "fundamental law of highway congestion" posits that road expansions are met with proportional traffic increases. Research has found that public transit investments have no effect on aggregate VMT, while road investments raise VMT proportionally (Duranton and Turner 2009). This research suggests that road investments raise VMT mostly by encouraging additional household driving and inducing more commercial driving.[9]

Third: Transit investments typically aim to serve commutes, which occur at peak times on the most congested routes. But commuting accounts for only 27 percent of total VMT. Non-commute trips like those

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[7] All sites studied were "within reasonable walking distance" of a TOD. Since residents elsewhere in the cities studied were much less likely to commute by transit, distance to transit affects transit ridership outside walking distance from a TOD.

[8] Data on commuting patterns in this section come from the 1990 Census and the 2008 American Community Survey. Data on VMT come from the Federal Highway Administration's Annual Highway Statistics.

[9] An extensive research literature on "induced travel demand" dates back to Downs (1962).

to stores, schools, and family or social events are much less likely than commute trips to use transit.[10] Thus, increased transit investment and commute ridership could displace, at best, only a fraction of total VMT.

Therefore, transit investments might not reduce overall VMT. But public transit investments may be desirable for other reasons, not least for expanding transportation options without raising VMT as much as road investments would.

[10] Hu and Reuscher (2004), Tables 6 and 9.

How Land Use and Transportation Connect

The relationship between land use patterns and transportation is "the most heavily researched subject in urban planning" (Ewing and Cervero 2010). This section reviews the evidence on the effect of land use patterns on transportation behaviors, and conversely, the effect of transportation features (like transit stations) on land values and development.

The Effect of Land Use on Transportation

In their wide-ranging research review and meta-analysis, Ewing and Cervero (2010) conclude that land use patterns have a modest but often statistically significant effect on transportation behaviors. As they point out, many studies of this question fail to consider causality: an observed relationship between, for instance, density and VMT could be caused by people who prefer transit choosing to settle in higher-density neighborhoods, rather than neighborhood density actually changing the travel behavior of residents. However, studies attempting to assess causality by controlling for individuals' attitudes or focusing on people moving to different neighborhoods (Handy, Cao, and Mokhtarian 2005) have generally confirmed that density actually does affect travel behavior (Ewing and Cervero 2010).

The extent of a relationship between land use and transportation behaviors varies by different components: trip length, trip frequency, and "mode choice"—whether people travel by car, transit, or other means. Of these components, trip length and mode choice are most affected by local land use patterns. Trip frequency is determined primarily by household socioeconomic characteristics (Ewing and Cervero 2001).

Among measures of land use patterns, two "destination accessibility" measures—"job accessibility by auto" and living closer to downtown—have the strongest relationship to VMT (Ewing and Cervero 2010). Put simply, people who live closer to jobs or other destinations drive less. The relationship between proximity to jobs and VMT is strongest when proximity is defined as the availability of jobs within four miles of home, and this "jobs-housing" balance is more strongly related to VMT than the proximity of retail and services (Cervero and Duncan 2006).[11] Design attributes of street networks, such as short blocks and many intersections, also reduce VMT by encouraging walking and transit ridership. Controlling for these various land use measures, residential density has a weak relationship with VMT, and the relationship between employment density and VMT is even weaker (Ewing and Cervero 2010).

However, some land use measures are correlated with density: for instance, densities are higher closer to downtown, where blocks tend to be shorter and destinations more accessible by transit. Furthermore, focusing on the independent effect of each land use measure, holding other measures constant, may understate the overall effect of the built environment on transportation. Policies designed to change one land use measure in fact change related measures as well, so the effect of land use on transportation behaviors may be, as Ewing and Cervero (2010) note, "quite large" even though the relationship between many individual land use measures and transportation behaviors is small.

[11] Measures of the jobs-housing balance for places in California are available from PPIC on request.

From a policy perspective, what is "quite large"? The Transportation Research Board (2009) concluded that doubling residential density would lead to a 5–12 percent reduction in VMT, and possibly up to a 25 percent reduction with complementary changes in transit availability, the jobs-housing balance, and other factors. The committee involved in this research effort disagreed on how large an increase in residential density would be feasible and reported two scenarios. In the first scenario, 25 percent of new residential development would be twice as dense as typical new development, and residents of new developments would reduce VMT by 12 percent; as a result, overall VMT reductions over the period 2000–2050 relative to the base case would be roughly 1.5 percent. In the second scenario, 75 percent of new residential developments would be that dense, and residents of these new developments would reduce VMT by 25 percent; as a result, overall VMT reductions would be roughly 10 percent (TRB 2009, Table 5-2).[12]

The research literature suggests that integrated policies—such as those including both land use and transportation components—have a greater effect on VMT than land use policies alone. The Transportation Research Board (2009) report also considered a scenario of higher density *plus* complementary changes like transit availability that would lead to twice as large a VMT reduction as the upper-bound estimate of higher density alone. Rodier's (2009) review of studies modeling the effect of land use, transportation, and pricing policies on VMT echoes this conclusion. Among the studies she reviews, transit policies alone (like service improvements) resulted in a median VMT reduction of 0.9 percent over 20 years; land use policies alone (like increased density) resulted in a median VMT reduction of 1.1 percent. But combined land use/transit policy scenarios resulted in a median VMT reduction of 8.1 percent. The estimated effect of integrated policies was far greater than the sum of land use and transit policies on their own. Some of this larger-than-additive effect arises because the models used to estimate effects of integrated policy scenarios deliver larger VMT reductions than simpler models do, even for the same policy (Rodier 2009). Nonetheless, some of the synergy appears to be due to policy coordination, not just methodological differences in the models.[13]

[12] TRB (2009) considered only residential density, not commercial/employment density, noting that forecasting commercial densities involved greater uncertainty and that modeling the relationship between commercial density and VMT were "beyond the resources of the study" even though the committee "recognized the importance of commercial development" (p. 148).

[13] A third policy category, focusing on pricing, had larger effects: Cordon, congestion, and parking pricing policies, taken singly, had larger VMT reductions than land use or transit policies taken singly, and VMT and fuel taxes had dramatically larger VMT reductions than all other policies. But the maximum reductions were associated with coordinated land use – transit – pricing policies.

Beyond transportation: How land use affects emissions

Land use patterns affect emissions in many ways apart from transportation. Residents of center cities produce fewer emissions than suburban residents not only because of different transportation behaviors but also because city residents are more likely to live in smaller housing units, which consume less electricity (Kahn 2010). And residential emissions, through transportation, home heating, and electricity, vary not only across neighborhoods but also across metropolitan areas (Glaeser and Kahn 2010).

In several temperate California cities, per-household carbon emissions are lowest in the nation. These emissions are highest in several southern and southwestern U.S. cities, where demand for air-conditioning is high: per-household emissions are nearly twice as high in Memphis as in San Jose. Such comparisons suggest that the distribution of population across metropolitan areas could have a marked effect on overall national emissions. Strategies that could encourage growth in lower-emissions areas include a national carbon tax or, at the local level, relaxing restrictions on development in lower-emissions areas.*

* Glaeser and Kahn (2010) find that land-use regulations are more restrictive in lower-emissions areas like Los Angeles, San Francisco, San Jose, and San Diego than elsewhere.

Employment Patterns Affect Transit Use More Than Residential Patterns Do

Research on land use patterns and their relationship with transportation has focused primarily on residential land use rather than on commercial land use.[14] Residential density around transit nodes, residents' travel patterns, and residential land use receive more attention in the research and policy literature than employment density, workers' travel patterns, and commercial land use do. One reason for this disparity is that data on population and housing for small geographic areas, like Census tracts, are more widely available than analogous data on employment, making it easier to measure patterns and trends in residential land use. Also, the classic land-use model that underpins the urban economics and planning literatures—the monocentric city model—assumes all employment to be at the city center, and that people make residential decisions based on commuting distance from their downtown jobs, the cost of housing, and other factors. Numerous policy studies and recommendations have focused primarily or exclusively on residential density and residential growth near transit stations (Transportation Research Board 2009; Calthorpe Associates 2010; Metropolitan Transportation Commission 2010). They rarely focus on employment patterns or growth.

Recent work, however, has challenged the traditional emphasis on housing density and residential land-use patterns by arguing that the location of employment matters critically to transportation behaviors. Employment densities and workplace proximity to transit are at least as important as residential patterns for achieving transportation goals (Frank and Pivo 1994). Theoretically, workplace proximity to transit should matter *more* for transit ridership than residential proximity to transit because "unlike the home end of the

[14] Throughout the paper, "commercial" land use or development refers to all forms of non-residential land use or development – including retail, office, and industrial.

trip, where there are many options for accessing transit, generally, walking is the only available option at the work end" (Barnes 2005). Accordingly, employment densities at trip destinations affect ridership more than residential densities at trip origins (Arrington and Cervero, 2008; Transportation Research Board 2009).[15] Furthermore, achieving high commercial densities is often more feasible politically than achieving high residential densities (Barnes 2005). Yet these research conclusions have not yet been fully incorporated into policy: "Connecting destinations to create ridership may seem like an obvious conclusion, but plans and policies have not reflected this approach. Most TOD policy have [*sic*] focused on residential development, rather than promoting agglomeration of jobs and commercial space in regional centers served by transit" (Center for Transit-Oriented Development 2009, p. 28).

Our own analysis confirms this.[16] Looking across all metropolitan areas in the United States, those with higher density have higher transit ridership, but the magnitude of the relationship between employment density and transit ridership is twice as large as that between residential density and transit ridership. Furthermore, metropolitan areas where employment is more centralized in downtowns have higher transit ridership, even after taking residential and employment density into account. At the neighborhood level, transit ridership is higher both among residents of a Census tract where tract residential density is higher and among workers in a Census tract where tract employment density is higher. And again, the relationship is slightly stronger for workers and employment density.[17] Transit investments, particularly in fixed-line systems such as subways, railroads, and streetcars, involve large capital costs that make economic sense only if potential ridership is high: denser areas support more transit investment, offer greater transit access, and have higher transit ridership. California's relatively low employment density—especially outside of the San Francisco-Oakland metropolitan area—is therefore a challenge for supporting transit investments and raising ridership.

The Effect of Transportation on Land Use

Just as land use patterns influence transportation behaviors, transit investments have the potential to influence land use outcomes, including land values and densities. Over small geographic areas, such as a neighborhood or the one-quarter or one-half-mile circle around a transit station discussed earlier, transit investments could raise nearby property values if the increased accessibility raises demand in the immediate area for residential or commercial space. Increased demand could, in turn, lead to higher residential or commercial densities, in the absence of constraints on development. Alternatively, land values could fall if transit and any associated development create problems such as congestion or noise. The relationship between transit and surrounding land values and densities depends both on how businesses and residents value proximity to transit and on public-sector decisions about zoning, land use, and other incentives for transit-oriented development. This section reviews recent research on land use outcomes around transit stations.

Most of this research looks at property values rather than density. Giuliano and Agarwal (2010) consider changes in density to be only a "second-best measure" as a proxy for land values because changes in land value will affect density only if zoning and other land use policies permit. In reviewing the literature on

[15] Employment near transit in more residential areas has the additional advantage of encouraging "bi-directional ridership," maximizing the usage of transit infrastructure rather than trains running empty in the non-commute direction (Center for Transit-Oriented Development, 2008).

[16] See appendix for details.

[17] The standardized beta from a tract-level regression of residents' transit ridership on log residential density is .38, and the standardized beta from a tract-level regression of workers' transit ridership on log employment density is .47. Both coefficients are statistically significant, and both regressions include metropolitan-area fixed-effects.

transit and property values, Cervero, Ferrell, and Murphy (2002) emphasize that "numerous" studies find a positive relationship with property values, while Giuliano and Agarwal (2010) conclude that "results are quite mixed," in part due to different research methods.[18]

However, for assessing the contribution of transit access to outcomes like transit ridership and resulting VMT reduction, density is more relevant than land value. A new transit station that raises surrounding land values but leaves densities unchanged will have a smaller effect on overall transit ridership than a transit station near which land values rise less but densities increase. Higher densities mean more residents, workers, or both are in close proximity to transit, which—as shown in the previous section—raises ridership. At the same time, zoning could prevent people who would use transit from moving close to transit stations (Cervero 2007).

Fewer studies have looked at land use changes, such as density, around new transit stations. Cervero and Landis (1997) found minimal impact of new BART stations in the San Francisco Bay Area on office construction and employment. Most new development was near freeways, not BART, though employment did increase around stations in downtown San Francisco, downtown Oakland, and a few other stations.[19] Reviewing numerous studies of land use patterns around transit stations, Giuliano and Agarwal (2010) conclude that "rail transit does not consistently lead to significant land use changes," and the land use changes that do occur are facilitated by complementary land use policies like development incentives and "stringent" parking management policies.[20] Yet the relationship between transit investment and land use patterns is far from settled. The Transportation Research Board (2009) called for further study of metropolitan employment patterns, of the development of employment sub-centers, and of "before-and-after studies of policy interventions to promote more compact, mixed-use development" (p. 205).

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[18] Lin (2002), Redfearn (2009), Mathur and Ferrell (2009), and Debrezion et al. (2007) assess property value changes around transit stations using various methodologies.

[19] Cervero and Landis (1997) measure employment at the ZIP code level using Census County Business Patterns, as well as employment aggregate data from the Census Transportation Planning Package. They measure office construction annually at the parcel level using property tax records. They find office construction greater around BART stations where the level of employment density is higher. However, they measure employment density in 1990, close to the end of the interval over which the dependent variable, office construction, is measured (1973–1993), which brings into question their conclusion that employment density helps to explain the variation in office construction rates.

[20] They provide detail reviews of studies in Portland, the San Francisco Bay Area (Cervero and Landis 1997), and Atlanta.

Transit and Development in California

Transit-oriented development is a prime example of the type of integrated land use and transportation planning that has the potential to reduce VMT as envisioned under SB 375. California already has experience with transit-oriented development and strategies for future development. Did California have success in raising densities near new transit stations to maximize transit ridership and VMT reductions prior to SB 375 implementation? This section evaluates growth around all new transit stations in California between 1992 and 2006.

Transit Expansion in California

Our analysis of employment and residential growth and density around new transit nodes relies on data from the NETS, the Census, and information we collected on all new transit stations in California that became operational between 1992 and 2006. We included transit stations on fixed-line rail, subway, streetcar, and bus-rapid-transit (BRT) routes (we did not include standard or limited-stop bus lines). Compared to buses, fixed-line modes tend to offer faster speeds, cover longer distances, and have greater ridership capacity, making them more attractive anchors for TOD. The permanence of fixed-line transit stations also adds to their lure for associated land-use development, though this permanence also means that fixed-line routes, unlike buses, cannot be easily rerouted in response to changing development patterns or demand.[21]

The transit stations that opened in California between 1992 and 2006 were part of numerous systems throughout the major metropolitan areas of the state. In all, 217 stations opened, including extensions to BART in the San Francisco Bay Area, the Sacramento light rail system, the San Jose light rail system, San Francisco MUNI, and LA Metro Rail, and new or largely new systems like the Altamont Commuter Express, Coaster San Diego, the Harbor Transitway, and Metrolink Southern California (Table 5).[22] The only new stations excluded from this analysis were those that overlapped with pre-existing stations on other routes.[23] Dozens of additional stations have opened after 2006, are under construction, or are planned, such as SF MUNI's Third Street line, the LA Metro Rail Expo line to Culver City, a light rail line from Monterey to Castroville, and the South Bay Bus Rapid Transit line from downtown San Diego to the border.

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[21] Fixed-line routes have high capital costs and therefore represent a notable share of California's investment in transportation and presumably the vast majority of transit capital investments. Over the past three decades, transit investments have accounted for 20 to 30 percent of all transportation capital expenditures (Bedsworth, Hanak, and Kolko 2011).

[22] Information on these stations, including exact address and opening date, was gathered from transit system websites and from the National Transportation Atlas Database compiled by the Bureau of Transportation Statistics.

[23] The main instance of this overlap was the Market Street portion of the San Francisco MUNI F-line streetcar, which runs directly above MUNI Metro lines and BART trains. The F-line portion along the San Francisco wharves, however, does not overlap older fixed-line transit routes and therefore was included.

TABLE 5
Fixed-line transit stations in California

System	Nodes open before 1992	New nodes, 1992–2006
Altamont Commuter Express	0	8
BART	33	10
Caltrain	31	1
Coaster San Diego	0	6
Harbor Transitway	0	7
LA Metro BRT	0	13
LA Metro Rail	22	40
Metrolink Southern California	1	52
MUNI fixed lines	110	17
Sacramento Light Rail	31	18
San Diego Trolley	36	16
San Jose Light Rail	34	29
TOTAL*	298	217

NOTE: Total nodes before 1992 double-counts some stations on multiple systems, like Montgomery MUNI and Montgomery BART in downtown San Francisco. Total new nodes (1992–2006) does not double-count any nodes and does not include nodes overlapping with older nodes, like the F-Market above-ground streetcar Montgomery stop in San Francisco.

New transit stations opening between 1992 and 2006 were located in areas with higher residential density and much higher employment density than areas more than one-half-mile from a transit station (Table 6).[24] This strategy is consistent with the need to deliver high ridership in order to support transit investments. However, density around newer transit stations was lower than density around transit stations that opened before 1992: older transit stations—such as the central portions of BART and the LA Metro Rail—are located in big-city downtowns, the places in the state with the highest employment density. Older systems that have expanded since 1992—BART and LA Metro Rail, as well as Sacramento Light Rail, the San Diego Trolley, and San Jose Light Rail—have typically added new stations by extending lines outward rather than by adding stations in dense downtowns.

TABLE 6
Residential and employment density for blockgroups around older nodes, newer nodes, and rest of state

	Residential density, 1990	Employment density, 1992
Within ½ mile of pre-1992 nodes	6864	32392
Within ½ mile of nodes opening 1992–2006 but not pre-1992 nodes	5627	11146
More than ½ mile from old or new nodes, in counties with transit nodes	3673	3969
Counties without transit nodes	1571	1368

NOTE: Density weighted by population or employment in the blockgroup.

New transit stations are also often located near a freeway. Many transit stations, in fact, are located in freeway medians, such as portions of the LA Metro Rail Green Line and many BART stations in the East Bay. Medians have the advantage of being an existing right-of-way, as opposed to land already occupied with

[24] Employment density is the main factor. Residential density does not positively affect the location of new transit stations holding other factors, including employment density, constant.

other uses, but stations in medians may pose a challenge for land-use development since the area immediately adjacent to the station is the freeway, which makes pedestrian access more difficult (though proximity to a freeway could facilitate park-and-ride usage).

These patterns are consistent with maximizing the potential for transit ridership through transit investments. Transportation policy in California has successfully located transit stations in higher density areas, which should therefore lead to higher transit ridership and, in turn, greater VMT reduction for the metropolitan area or region.

Employment Growth Around New Transit Stations

In the context of SB 375 and integrated land use/transportation planning, steering growth toward new transit stations is expected to increase the share of residents, workers, or both near stations, thus raising overall transit ridership and lowering VMT. Encouraging growth around transit stations could also be an economic development strategy in itself to increase employment opportunities in a given area, but economic development is often at best a secondary goal of transportation planning, even when integrated with land-use planning (California Department of Transportation 2002 and 2010).

As noted earlier, our primary research focus is employment growth, rather than residential growth, property values, or other measures. And as demonstrated above, employment patterns are at least as important for transit ridership as residential patterns. The NETS provides data on employment on an annual basis at the street address level, which allows us to estimate employment counts within a precise distance of a transit station, just before and after the station opens. Information on residential trends is not available with comparable frequency or geographic specificity.

For assessing the potential contribution of transit investments to VMT reduction, changes in density are a better measure than changes in property values, even though changes in property values may be a better indicator of the economic development impact of transit investments (Giuliano and Agarwal 2010). Economic theory suggests that an increase in demand for land puts upward pressure on land values and induces development unless restricted by zoning or other constraints. Thus, increased density around a new transit station would mean that the demand for land around the station increased AND new development was permitted. An increase in land values WITHOUT an increase in density would still reflect an increase in demand for land around the transit station, but less potential for VMT reduction because the number of people or jobs near the transit station (and therefore likely to use transit) did not increase.

Assessing density rather than land value changes has another methodological implication. While the announcement of a new transit station might immediately raise the value of surrounding land through “capitalization,” density probably would not increase until the station is operational.[25] When a station is announced, developers might immediately bid up the price of the surrounding land in anticipation of the greater demand for tenants in their developments, but theoretically we should expect a business seeking to locate near the new transit station to be willing to pay the increased rent only once the station opens, making the location more accessible. Therefore, studies of property values around transit stations, should consider planned station announcements; in contrast, this research on density focuses on station opening dates.

[25] In their review, Giuliano and Agarwal (2010) note that some of the studies reporting higher land values around stations examined the period after stations were announced but before they were completed.

Analyzing employment changes around transit stations raises additional methodological issues. The first is choosing an appropriately sized area of land around the station. The research literature and the above findings on transit proximity and usage suggest a steep drop-off in usage starting one-quarter-mile beyond the station, which increases even more beyond one-half-mile. In our analysis, we focus on density changes in both the one-quarter-mile and the one-half-mile circle around the transit station.[26]

The second methodological issue involves how to assess the relationship between employment density changes and transit station openings: Are these changes associated with the station opening or would they have happened anyway? We use the difference-in-differences approach, comparing employment growth before and after a station opens with employment growth in a comparison area that should be affected by the same economic trends and is as similar as possible to the transit station area except for actually having a transit station. The comparison area for each transit station is a set of twenty nearby (though not necessarily adjacent or contiguous) Census blockgroups, selected for their similarity to the transit station area on measures such as density and proximity to the central business district, to older transit stations, and to highways. Using regression analysis, we estimate the change in employment growth associated with the opening of a transit station, relative to the comparison areas, controlling for other factors. This method can be used to estimate employment growth associated with the opening of a particular transit station or the average employment growth associated with the full set of transit stations that opened after 1992 and before 2006.[27] Full technical details about this methodology and results are in the Technical Appendix.

Averaging across all new transit stations, employment growth is one percentage point *lower* after a station opens than before it opened, relative to the comparison area. However, this difference from zero is not statistically significant, meaning that the true effect may be zero rather than negative. There is no evidence of faster employment growth one, two, or three or more years after the station opens than before it opened, either. Areas around new transit stations do exhibit faster employment growth than comparison areas *before the station opens*—so new transit stations tend to be located in areas where employment growth was *already* faster than comparison areas. Despite this, the opening of the new transit station was not associated with any boost in employment growth, which is what one would expect if the transit station opening raised demand for land and builders could respond with new development.

Although the average employment growth associated with a new transit station opening is not statistically significant, the employment growth associated with the opening of individual transit stations ranged from large, statistically significant increases to large, statistically significant declines. Of 204 stations that opened between 1992 and 2006, 18 exhibited statistically significant, positive employment change in the surrounding area relative to comparison areas; 20 exhibited statistically significant, negative employment change in the surrounding area relative to comparison areas. Figures 2 and 3 illustrate the employment growth associated with the opening of new transit stations in the Los Angeles and Sacramento areas, respectively, relative to comparison areas. Blue circles indicate faster employment growth in the station areas than in comparison areas, red circles indicate slower employment growth in the station areas, filled-in circles indicate statistical significance, and the size of the circle reflects the size of the growth differential. These figures show that transit stations whose openings were associated with faster employment growth were scattered across

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[26] The analysis considers employment growth for a fixed area – one-quarter or one-half-mile – around the transit station. Density is employment divided by land area. Thus, when looking at the same land area over time, a change in employment is equivalent to a change in employment density.

[27] Because the NETS employment data covers 1992–2006, we only observe employment data after opening for stations opening in 1992 and only observe employment data before opening for stations opening in 2006. Our sample in the regression analysis includes the 204 transit stations that opened between 1993 and 2005.

regions and, within regions, across transit systems and routes. Some transit stations near each other exhibited similar patterns, but there are no consistent differences across regions, systems, or lines. Transit stations with statistically significant employment increases include the Hollywood/Highland and Hollywood/Vine stations on the LA Metro Rail, the Beach and Jones Streets stop near Fisherman's Wharf on the MUNI F Wharves line in San Francisco, and the Sylmar/San Fernando station on the Metrolink Antelope Valley line in Los Angeles County (see text box).

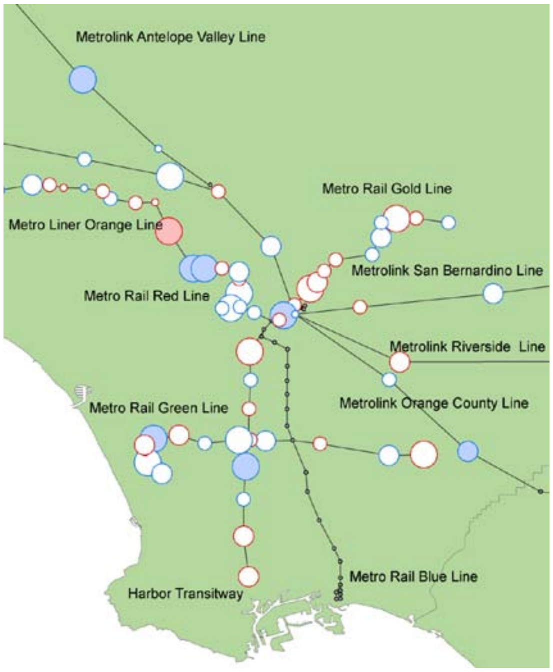
Different paths to employment growth: Hollywood/Highland and Sylmar/San Fernando

Stations associated with large, statistically significant increases in employment growth include the Hollywood/Highland and Hollywood/Vine stations on the LA Metro Rail Red Line in Hollywood and the Sylmar/San Fernando station on the Metrolink Antelope Valley line in Los Angeles County's northern San Fernando Valley. These stations were located in very different neighborhoods with very different TOD strategies.

The Hollywood/Highland underground subway station opened in 2000 and was a high-profile transit-oriented development project focused on retail and entertainment along Hollywood Boulevard. The Los Angeles Community Redevelopment Agency was integral in assembling land for development, negotiating financing with the city, and securing approvals for the $600 million project that resulted in the Hollywood & Highland Retail Center, the Renaissance Hollywood Hotel, and the Kodak Theater (Cervero et al. 2004; California Department of Transportation, 2002). Both the Hollywood/Highland and the neighboring Hollywood/Vine stations were dense, developed, mixed-use areas even before their station openings.

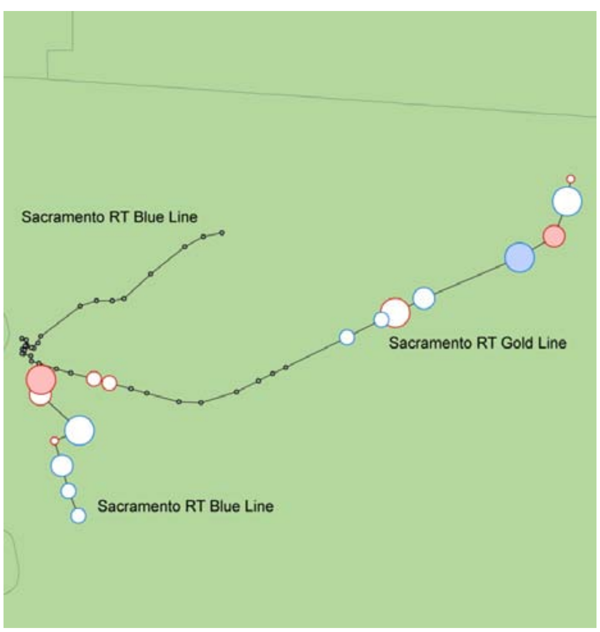
The Sylmar Metrolink station in Santa Clarita opened in 1994. The nearby "Montage at Village Green" housing development opened in 2000. Whereas most TODs focusing on housing are "mixed-use developments" incorporating some commercial space, the Montage was exclusively a housing development (Moses et al., 2009). Data from the NETS database reveal that employment growth that accompanied the station development included small businesses across numerous industries, including grocery wholesaling, light manufacturing, construction, and real estate brokerage. Many of these businesses were located between the station and the housing development. The Sylmar example shows that employment can grow around new stations even when the station TOD strategy emphasizes residential development.

FIGURE 2
Employment growth associated with station openings, Los Angeles area



NOTES: Size of circle reflects magnitude of employment change associated with station opening. The four sizes reflect employment changes of with magnitudes of less than 1 percent, 1–5 percent, 5–10 percent, and more than 10 percent. Blue circles are positive, and red circles are negative. Shaded circles indicate statistically significant relationships between employment change and station opening. Stations in existence before the period of study are shown with black dots.

FIGURE 3
Employment growth associated with station openings, Sacramento area



NOTES: Size of circle reflects magnitude of employment change associated with station opening. The four sizes reflect employment changes of with magnitudes of less than 1 percent, 1–5 percent, 5–10 percent, and more than 10 percent. Blue circles are positive, and red circles are negative. Shaded circles indicate statistically significant relationships between employment change and station opening. Stations in existence before the period of study are shown with black dots.

A more systematic approach to explaining these variations in employment growth is to extend the regression model to include variables that might affect the relationship between transit and employment growth. The Technical Appendix describes these statistical "interactions" and presents the details. The main findings are that employment growth associated with transit station opening tends to be higher when transit stations are:

1. surrounded by higher residential density;
2. surrounded by higher employment density;[28]
3. farther from an older transit station.

Other variables, like the distance from the transit station to the downtown or to the nearest highway and the stringency of local growth restrictions, did not affect the whether a new transit station was associated with faster employment growth.[29]

Just as transit station openings were not, on average, associated with faster employment growth overall, station openings were not associated with consistent employment growth patterns in specific industries. The composition of employment near transit stations differs from the composition of employment in the economy overall. Near transit stations, sectors like wholesale trade, finance, professional services, and government are disproportionately represented; personal services, retail, education, construction, and other industries that tend to serve consumers rather than business tend not to locate near transit stations.[30] But the industries that tend to be located near transit stations did not exhibit faster employment growth *associated with new transit stations opening*.

Our main finding, that there was no increase in employment growth associated with transit stations opening, runs counter to a goal of transit-oriented development. We also find that TOD strategies have been unsuccessful, on average, in promoting residential development, which is generally the focus of these strategies: in fact, residential growth appears to have been significantly *slower* in the areas around new transit stations than in comparison areas. However, the residential growth data are less frequent and less current than the employment growth data, so the residential growth results do not reflect before-and-after changes in the same way that the employment growth results do. We therefore emphasize the employment growth results.[31]

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[28] The relationship between employment growth and initial density was positive and statistically significant for only residential density, not employment density, for the one-quarter-mile circle around the transit station. In contrast, the relationship was positive and statistically significant for only employment density, not residential density, for the one-half-mile circle. For both the one-quarter- and one-half-mile circles around the transit station, the relationship between employment growth and employment density was approximately twice as large as the relationship between employment growth and residential density.

[29] Some of these factors did affect employment growth generally even if they did not affect the association between a transit station opening and *additional* employment growth. Employment in general grew faster in blockgroups closer to a freeway, closer to the CBD, and with less restrictive regulation, as well as in areas with lower residential density and lower employment density. See the "main effects" results from the interactive specification in the Technical Appendix. Tracts identified as the CBD of metropolitan areas are available from PPIC on request.

[30] Transit stations tend to be closer to the CBD, closer to highways, and in areas with higher employment density and lower population density, all else equal. These factors help explain the location of many industries, and adjusting for these factors, many of the differences in employment composition around transit stations are no longer statistically significant.

[31] The residential analysis is limited by the availability of Census population data, Census blockgroup population is available only for 1990 and 2000, whereas NETS employment data are available annually through 2006. The best one can do to assess residential growth is to compare population growth between 1990 and 2000 in areas where a transit station opened in that time period with population growth in comparison areas, controlling for the same variables as in the main analysis. Without annual population, one cannot compare population growth before and after the transit station opened using the same difference-in-differences framework. For example, if residential density declined between 1990 and 2000 around a station that opened in 1995, there is no way to tell whether that decline in residential occurred before or after the station opening in 1995.

Why Isn't Employment Growth Faster Around Transit Stations?

The lack of additional job growth around many new transit stations represents a missed opportunity for raising employment densities, increasing transit ridership, and lowering VMT. But it is consistent with how local officials focus their TOD efforts: Among localities with existing or planned projects to increase density around transit stations, projects were much more likely to emphasize residential than commercial uses. Regional transportation agencies appear to have been assuming that localities need more encouragement to build housing in the right places. In contrast, jobs—in the words of one transportation planner—are believed to "take care of themselves."[32]

These assumptions have probably taken root because land use policies in California have traditionally favored commercial (including industrial) development, both because these uses generate more local sales tax revenues and because it is generally believed that businesses require less expensive local public services than residents do (Boarnet and Crane 2001). Zoning practices reflect these assumptions: Land surrounding transit stations in Southern California in the mid-1990s was much more likely to be zoned for commercial/industrial use than for residential use, relative to other portions of the cities containing those transit stations (Boarnet and Crane 2001). More recently, a 2007 review of San Francisco Bay Area TOD policies reports that development goals for TODs include minimum density requirements for residential development but not for employment, in part because "cities already have considerable incentives to zone for non-residential uses, such as sales tax revenue and reduced fiscal impacts" (Nelson\Nygaard 2007, pp. 5–7).

But our evidence shows that employment growth around transit stations does *not* take care of itself, even if zoning around transit stations favors non-residential uses. Existing zoning that allows commercial or industrial use may not, by itself, be sufficient to spur employment growth; often, more explicit strategies to encourage commercial development are necessary. A set of case studies of San Diego stations concluded that TODs were most successful when they coincided with local authorities' development plans for the area (Boarnet and Crane 2001). A study of the Washington DC Metro found that dense development around new suburban stations hinged on the "determination and foresight" of local officials (Schrag 2006). The major Hollywood/Highland TOD illustrates the importance of authorities in regional transportation and local development working together, well beyond the creation of a favorable zoning plan.

Researchers and TOD advocates have identified specific policies to encourage development and transit ridership around transit stations. Parking policies are often recommended. For instance, relaxing requirements for developers to provide a minimum number of parking spaces in residential TODs could encourage denser residential development (Arrington and Cervero 2008). Similarly, restricting the availability or raising the cost of parking could encourage transit ridership (Giuliano and Agarwal 2010; Shoup 2004). Such policies would be a shift from current practice. Very few communities charge for parking anywhere, and nearly all require employers to provide parking in new commercial developments. Some communities are relaxing parking requirements for residential developments, consistent with the general tendency to integrate transportation policies more with residential land use than with commercial land use (Bedsworth, Hanak, and Stryjewski 2011).

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[32] Quote taken from interview with California transportation planner for companion paper, Bedsworth, Hanak, and Stryjewski (2011). They also report that over half (56%) of the communities with these projects reported that they were all or mostly residential, about a third (31%) were evenly split between residential and commercial, and 13 percent were mostly commercial.

Other land use policies, such as waiving floor-area-ratio and height restrictions and providing development incentives, can also encourage TOD (Giuliano and Agarwal 2010; Center for Transit-Oriented Development, 2008). Building a mix of TOD businesses, including retail and personal services that employees use during the day, encourages transit use by making it easier to run errands near the workplace (Center for Transit-Oriented Development, 2008). Bolstering connectivity—including local bus feeder service to transit stations and walkable, bikeable streets nearby—helps increase transit ridership around TODs and, in making the location more accessible, is likely to raise demand for the location (Center for Transit-Oriented Development 2008).

Despite these recommendations for making TOD more effective, reviews of TOD implementation suggest that the barriers to carrying them out are formidable. Some barriers to developing higher densities around transit stations are similar those faced by high-density development anywhere—these include challenges in demonstrating financial feasibility, organizational issues with transit and other public agencies, and local resistance to multi-family housing and dense infill development. But high-density development around transit stations also faces unique barriers, including parking, increased local traffic congestion, different goals of transit and development agencies, and challenges financing and designing mixed-use development (Cervero et al. 2004).

Conclusion

California's ability to achieve VMT reductions though land use changes associated with transit investments is mixed. Residential density in California is above the U.S. average and rising. But employment density is below the U.S. average and falling—and employment density is more closely associated than residential density with transit ridership, meaning that California's job-related land use patterns are less conducive to economically feasible transit investments than land use patterns in other states.

With the exception of San Francisco and Sacramento, California's large and mid-size metropolitan areas have low employment density relative to their residential density. Among large metropolitan areas in California, Sacramento and the Inland Empire have the lowest transit ridership among commuters. The higher employment density of Sacramento suggests that transit has potential to gain ridership there, though the low employment density in the Inland Empire—combined with relatively low residential density—suggest that potential for fixed-line transit investment and ridership in the Inland Empire may be quite limited.

Strategies to encourage density in California must focus at least as much on employment density as on residential density. Our findings emphasize that employment density is more closely tied to transit ridership than residential density is. We also highlight the importance of proximity to transit stations: for ridership levels, proximity is even more important for workers than for residents.

California's recent transit investments have been in high-density areas, particularly in high employment-density areas: This is good. Furthermore, new transit stations have been located in areas that had faster employment growth before the opening of the station, relative to comparison areas (adjusting for factors like residential and employment density and distance to the downtown and highways). However, transit station openings were associated with no increase in employment growth; the faster employment growth in areas where transit stations later open would have happened even in the absence of the station opening.

Since coordinated land use/transportation plans have included transit-oriented development to tie growth to new transit investments, the lack of additional growth represents a missed opportunity for raising densities, increasing transit ridership, and lowering VMT. It does not appear that employment growth suffered from competition with residential growth: despite the traditional focus on housing in transit-oriented development, residential densities *fell* over the period when new transit stations opened, while employment densities held roughly constant.

Even though transit station openings were not associated with increases in employment growth on average, some individual transit stations were associated with faster employment growth after they opened. The variation in employment growth across transit stations follows some patterns: employment growth increased more around new transit stations with higher initial residential and employment density and around new transit stations farther from older transit stations. One possible explanation: areas with higher density have zoning in place—or lack local opposition—that supports further development. At the same time, these findings imply that employment growth around transit stations does not hinge on having lots of vacant land, since transit does not appear to boost employment growth significantly in relatively undeveloped areas.

We also found that stations in the same system, on the same line, or even next to each other sometimes exhibit quite different changes to employment growth. Conditions around the transit station, including local zoning and other policies that could vary across stations, might therefore affect how much employment growth is associated with new transit stations.

It is surprising that, on average, employment growth around new transit stations was no faster than in comparison areas, which were selected because of their similarity in land uses, densities, and proximity to other transit stations and highways. It is especially surprising that even around lower-density primarily residential stations employment growth was, on average, no faster than it was in comparison areas, particularly because employment growth around stations in residential areas has additional benefits: increasing employment around stations that are largely suppliers of commuters toward downtown jobs can increase two-way utilization of costly rail capacity. Therefore, planners should aim to ensure that employment growth near stations, even those in residential areas, exceeds employment growth in nearby similar neighborhoods that lack transit access.

Researchers and practitioners point to parking, zoning, and urban design policies that could encourage development around new transit stations, as discussed above: these policies could provide encouragement to either residential or commercial development near transit. However, to encourage commercial development and employment growth specifically, existing zoning patterns and fiscal incentives—which traditionally favor commercial over residential development—have not been sufficient. Jobs do not, despite one planner's claim, "take care of themselves." Paradoxically, SB 375 could make employment growth around transit stations even more difficult to achieve because the law explicitly favors residential development in TODs: to receive exemptions from California Environmental Quality Act (CEQA) requirements, development projects near transit stations (called Transit Priority Projects) must be at least 50 percent residential, as measured by building square footage.[33] For California to reap the benefits that greater employment density around transit brings, the state should encourage commercial development relative to residential development near stations. Failing to take advantage of rail through more intense land development around stations is a significant missed opportunity to increase ridership and to make the most of costly transit investments.

Challenging as these TOD barriers are, questions about the ultimate impact of TOD on VMT reduction loom even larger. Even if land use policies and demand for space near transit were successful in raising densities near transit, the effect on regional VMT would likely be small. As noted above, three-quarters of workers within one-half mile of a transit station drive to work, most of them driving alone. Even within one-quarter-mile of a transit station—just a five-minute walk—only 10 percent of workers commute via fixed-line transit. Past transit investments in California have not gotten commuters out of their cars. Furthermore, commute trips account for only 27 percent of VMT, and trips for other purposes—school, social, personal business—are much less likely to occur on transit. Research examining transportation behaviors for metropolitan residents in aggregate, not just those near transit stations, concludes that transit investments have little impact on VMT, both because many new fixed-line transit commuters are former bus commuters, not former car commuters, and because transportation investments that initially might reduce congestion often induce additional driving.

And yet, integrating land use and transportation planning may contribute to GHG emissions reductions even in the absence of VMT reductions. If the planning encouraged by SB 375 succeeds in raising densities in California, emissions at the regional level could fall because higher-density residential units tend to be smaller and consume less energy. Furthermore, removing restrictions on residential or commercial

[33] SB 375's primary incentive to encourage localities to integrate their land use plans with regional transportation plans is exempting designated development projects from the CEQA environmental regulatory review process.

development would lower land prices and encourage population, economic activity, or both, to shift from other places to California, where the mild climate requires less energy for heating and cooling buildings. Within California, removing restrictions on development in milder coastal regions could shift some growth away from the inland areas with a more extreme climate, where California's fastest population growth is expected (Kolko, 2010). Faster growth in California relative to other parts of the United States, or in milder regions of California relative to inland areas, may not reduce GHG emissions per capita in any one region, and therefore might not meet the goals of SB 375. But shifting growth to lower-emissions-producing areas could reduce per-capita emissions at the national or state level.[34] SB 375 may contribute to emissions reductions, however inadvertently, beyond those related to VMT reductions.

[34] And perhaps significantly. Glaeser and Kahn's (2010) estimates, reviewed above, show per-carbon household emissions as almost twice as high in some other parts of the United States than in some California regions.

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About the Author

Jed Kolko is an associate director of research at the Public Policy Institute of California, responsible for managing the institute's economy research. He has conducted numerous studies of the California economy, economic development, housing, and technology policy. Prior to coming to PPIC in 2006, he was vice president and research director at Forrester Research, a technology consultancy, where he managed the company's consumer market research businesses and served as the lead researcher on consumer devices and access technologies. Jed has also worked at the Office of Federal Housing Enterprise Oversight, the World Bank, and the Progressive Policy Institute. He holds a Ph.D. in economics from Harvard University.

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PPIC | PUBLIC POLICY INSTITUTE OF CALIFORNIA

PUBLIC POLICY INSTITUTE OF CALIFORNIA
500 Washington Street, Suite 600
San Francisco, California 94111
phone: 415.291.4400
fax: 415.291.4401
www.ppic.org

PPIC SACRAMENTO CENTER
Senator Office Building
1121 L Street, Suite 801
Sacramento, California 95814
phone: 916.440.1120
fax: 916.440.1121