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Parking, travel behavior, and working from home

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Abstract: We examine parking policy's potential to influence people's travel behavior, including their decision to work from home. Drawing on the California Household Travel Survey, we first show that most households have residential parking included in the rent or purchase price of their home, that most employed individuals have free parking at work, and most vehicle trips end with a free parking space, usually off-street. Furthermore, we confirm that most cars are mostly parked; the median household vehicle in California spends 23 hours a day parked. Using regression models, we uncover strong associations between choosing to drive and having free parking at work or home. We find that households with bundled parking are more likely to drive, and less likely to use transit. We further find that employees with free parking at work are more likely to drive for their commutes. Finally, we estimate regressions that analyze the decision to work from home. Data constraints make these regressions less conclusive, but our results suggest, consistent with previous literature, that working from home is associated with more, rather than less, vehicle travel.

Keywords: Parking, travel behavior, VMT, commute, telework

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1 Introduction

Driving stands out among transportation modes for its high terminal costs: the time and space needed to park. The promise of automobility is to go where one wants, when one wants, but fulfilling that promise requires having a place to store the vehicle when one arrives. This requirement makes driving different from other modes. While the typical train or bus spends most of its life in motion, the typical automobile spends most of its life parked.

In an unregulated market, or one where land values are high, parking's large temporal and spatial demands could make owning and using a vehicle expensive. Most of the United States, however, doesn't fit this description: in many places land values are low, and in almost all places the market for parking is not just highly regulated, but regulated in a way that depresses parking's price. Cities keep most of their curb spaces free and require almost all new developments to provide ample parking off-street. This combination, of a price ceiling on the street and a quantity floor off it, shields most

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drivers from parking's full cost. Because parking is a complement to driving, policies that keep its price down and its supply up make driving less expensive (Shoup, 2011).

The implied subsidy here is large, and has both academic and policy relevance. On the academic side, regulations that keep parking abundant and cheap help clarify some stylized facts about transportation and land use that might otherwise be puzzling. Off-street parking, for example, is a low-value land use, generating little revenue or employment, and for that reason is often prevalent in declining cities (Eckerson, 2014). More surprisingly, however, is that off-street parking is also often plentiful in economically vibrant places, like San Jose, where land values are high. Parking requirements, which mandate parking's presence regardless of its opportunity costs, help resolve this paradox (Gabbe et al., 2020).

Required parking also helps explain the emergence, in the late twentieth century, of "dense sprawl" or "car-oriented density" (Eidlin, 2010): the phenomenon by which urban areas become denser while remaining deeply inhospitable to non-auto modes. Relative to other US metropolitan areas, for example, Los Angeles and New York are quite dense. But Los Angeles has more vehicle ownership and driving than its density alone would predict, while New York has less. The difference lies, in part, in the availability of parking. Almost every housing unit in Los Angeles comes with a parking space, while about 70 percent of units in New York City do not (Manville, 2017; Manville et al., 2013; Manville & Shoup, 2005; Shoup, 2011).

Regulation's role in these situations gives parking a strong policy valence. While parking is unlikely to be the largest determinant of whether and how much a household drives—income and family size are probably larger predictors—parking, unlike these other factors, lends itself to government action. Policymakers have neither a ready means nor (hopefully) a strong motivation to reduce family size or household income. But cities already regulate parking, and they could with relative ease change the manner of that regulation. They could require less parking (or none), charge more for their curb parking, and allow development in places that are currently parking lots.

Parking's potential to influence travel behavior is the topic of this paper. The idea of using parking as a policy lever is not new, but COVID-19 and its aftermath have arguably endowed it with renewed urgency. The pandemic and its associated lockdown demonstrated the benefits of reduced private vehicle travel, showed the importance as well as the vulnerability of public transit, and helped reveal the opportunity costs of abundant parking. At the pandemic's onset, large amounts of work immediately became remote, and large amounts also simply stopped. While the lockdowns' economic costs were immense, they also offered a window into the potential environmental benefits associated with less driving. Vehicle travel plunged, which led congestion and air pollution to steeply decline (Bao & Zhang, 2020; Laughner et al., 2021; Mueller et al., 2022; Pishue, 2021). On the other hand, stay-at-home orders also sent public transit systems, many of them struggling even before the coronavirus, into further distress. Then, as the pandemic persisted and restaurants in particular battled to stay afloat, cities began repurposing parking spaces, relaxing requirements and allowing restaurants to operate in parking lots and curb parking spaces.[1]

COVID's retreat has reversed some of these trends but not others, raising important questions about the future direction of sustainable transportation. Remote work is not as

[1] Examples in Los Angeles include the city's Al Fresco Dining Ordinance (Los Angeles Department of City Planning 2023) and its Curbside Dining Program (Los Angeles Department of Transportation 2023). Grabar (2023) discusses programs nationwide.

common as it was at the pandemic's peak but remains far more common than it was pre-COVID. Driving, congestion and pollution have also returned, rivaling and in some cases exceeding pre-pandemic levels. Transit ridership, however, has not recovered—in part because remote work has persisted disproportionately among educated workers employed by large firms (Barrero et al., 2023). While most of these workers had not been transit commuters, the large transit systems that account for most US transit ridership had relied heavily on these workers. Telework, as such, drained transit of many of its core riders. Finally, local governments seem ambivalent about the future of curbs and parking spaces. Some have continued to allow open-air dining in parking spaces, while others have returned these spaces to exclusive use for vehicles.

In this context, it is worth revisiting the role that parking policy can play in travel decisions. We do so by drawing on the 2010-2012 California Household Travel Survey (CHTS). The CHTS is an older dataset, but also a novel one, and for reasons we will discuss, we believe the relationships we document using the CHTS remain relevant today. The CHTS is a large, representative travel diary from the US's largest state, and, at the time of our study, unique among large travel diaries for offering fine-grained data on the use and price of parking spaces away from home.[2] Across thousands of users and a broad spectrum of built environments, the CHTS records if a given trip used parking, if the driver paid for it and (if they did) its price, if the parking was on- or off-street, and so on. We match these data both to measures of the built environment and to household and individual characteristics and estimate the association between parking availability and the decision to travel (or not) in different ways.

Specifically, we estimate the associations between parking availability and decisions to work from home, drive, and use public transportation. Our first major result is descriptive. We confirm something that has long been anecdotally intuitive, but never empirically verified, which is the sheer prevalence, in space and time, of free parking. The vast majority of California vehicle trips end in a parking space — the typical vehicle is parked almost 23 hours a day—and the vast majority of those spaces, both on- and off-street, are unpriced.

We then estimate regressions demonstrating that, even controlling for a host of other factors, the presence of free parking is strongly associated with more vehicle ownership, more driving, and less transit use. Our final regressions measure the association between free parking and working from home. Here the CHTS has some deficiencies, primarily in the way it measures home-based work, and for that reason, we expect this relationship to be weaker, and it is. Consistent with other literature, however, we cannot say with certainty that working from home results in less total driving.

The next section of this article reviews some relevant literature on parking, travel behavior, and remote work. We pay particular attention to the determinants of telework, since this is the area where the least is known. Section 3 describes our data and empirical approach. Section 4 presents and discusses our results, and Section 5 concludes.

2 Background

We draw on and contribute to two literatures: the literature examining transportation and land use (and specifically transportation and parking) and the literature that studies

[2] The 2022 National Household Travel Survey (NHTS), which was released after we had completed this study, includes some parking variables as well.

the determinants of remote work. Both literatures are large: the first is legitimately vast, and the second is growing rapidly as a result of COVID-19. We review each in turn.

2.1 Parking, travel behavior and the built environment

Parking occupies a relatively small portion of the transportation and land use literature, because parking was for a long time a neglected aspect of the transportation and land use connection. Parking's time in the academic wilderness, however, has ended, and it is no longer controversial to suggest that the ease and expense of storing a vehicle influence the decision to own one, or to use it for any given trip. A diverse body of evidence now suggests that when parking's price is low, people are more likely to own vehicles, more likely to use them, and less likely to ride transit (Chatman, 2013; Manville, 2017; Manville & Pinski, 2020; Millard-Ball et al., 2022; Shoup, 2011; Weinberger 2012; Weinberger et al., 2009).

At the same time, this evidence base is smaller than the evidence base associated with other aspects of transportation and land use, such as the relationship between driving and population density. This is so because measures of parking continue to be absent from most data sets. Both large social science surveys and big administrative data sets offer detailed information, over time and for the entire United States, on commuting behavior, the quantity of overall travel, the supply of roads, the count of vehicles, and the density of jobs, people and housing. In contrast, almost no systematic data sheds light on the supply, price and availability of parking, particularly outside the home. As an example, the 1995 National Personal Transportation Survey asked respondents dozens of questions and had them fill out a detailed travel diary. It asked only one question, however, about parking (did employed respondents pay to park at work?). Three subsequent versions of the NPTS—the National Household Travel Surveys of 2001, 2009 and 2017—were longer than the 1995 survey, and did not ask about parking at all. This omission renders the NHTS, a workhorse of the travel behavior literature, largely inutile for studies of parking. Currans et al. (2023), used the 2017 NHTS to argue that housing developments with less than one parking space per unit are associated with less car ownership and vehicle travel, but because the NHTS lacks parking data, they had to infer its presence using secondary methods.

As a result of these data limitations, the empirical literature on parking is characterized by a combination of detailed data from limited contexts, and limited data from more general contexts. An example of the former is Millard-Ball et al. (2022) who administered a travel survey to residents of affordable housing in San Francisco, and showed that compared to households assigned units with parking, households without parking drove less and rode transit more. Because San Francisco assigns affordable housing units to tenants via lottery, these findings avoid self-selection problems and are plausibly causal. They are, however, drawn from a particular subset of housing in one city, so a skeptic might question their generalizability.[3]

An example of the latter is Manville (2017), which uses data from the American Housing Survey (AHS) to show that households with bundled parking—parking included in the unit's rent or purchase price—were more likely to own vehicles and drive to work. This finding was robust to tests for self-selection and drew on more general data (the AHS is a representative sample of the US housing stock). The data were, however, less

[3] A point in the paper's defense is that housing in San Francisco is by now so expensive that families with incomes over $100,000 can qualify for subsidized units. So the inhabitants of subsidized housing are not automatically poor. Many have vehicles, or at least have income sufficient to get vehicles if they want them.

detailed. The AHS contains few travel behavior variables, and its parking measure only shows if the household has bundled parking. It does not show the number of spaces a household has, nor indicate the price or availability of parking at different destinations away from the home.

2.2 Parking and remote work

Data limitations notwithstanding, the hypothesized relationship between parking availability and the decision to drive is straightforward: the ease or price of parking influences the total cost (in time, money, or stress) of using a car, and as that cost rises, the likelihood of driving falls. The relationship between parking and telework is conceptually more complicated. First, parking availability, and the built environment in general, may not have a role in people's decision to telework, because their ability to do so is determined primarily by two other factors: the nature of the work and workplace norms. Second, when these two factors allow for teleworking, the price and availability of parking could, depending on the circumstances, encourage or discourage teleworking.

2.2.1 The determinants of telework

The decision to work from home, unlike the decision about how to get to work if one commutes, hinges primarily on the nature of the work itself. Retail clerks and grocery cashiers can, in principle, get to work any number of ways: drive, bike, walk, or take transit. Aspects of the built environment, including the availability of parking, could influence that decision. But these workers cannot work from home; by definition they must be physically present to help customers. Their decision to work from home or not has nothing to do with the built environment or their travel options, and more to do with the job itself.

The first condition for telework, then, is a job that can be flexibly executed outside the workplace. Industrial transformation and technological progress have, over time, placed more jobs into this category. As early as the 1970s, the rise of the information economy created a larger class of workers that could do work away from the office (Drennan, 2002). Telework at this time, however, would be slow, and communication would rely primarily on (then-expensive) phone calls. Few firms as a result adopted it (Bailey & Kurland, 2002; Di Martino & Wirth, 1990). The advent of high-speed home-based Internet, in the mid-aughts, removed some of these constraints and made telework more feasible (Barrero et al., 2023; Pyöriä, 2011). In the year 2000, only one percent of US adults had broadband Internet. In 2019, 73 percent did (Pew Research Center, nd). This is a key reason that information and telecommunication is the field most likely to be able to telework.

A job that can be done remotely, however, is not necessarily one that will. Even before the pandemic, substantial improvements had been made to online meeting platforms like Zoom, but telework remained quite rare (Pyöriä, 2011). A second condition for teleworking, then, is that a firm allows its employees to telework. Prior to COVID, many employers were reluctant to let workers be remote, even for jobs where telework was technologically feasible. This reluctance owed to a combination of three concerns: a fear that employee effort would fall; a fear that quality would fall even if effort did not; and a fear that productivity would fall even if effort and quality were constant, as a result of declines in serendipity and unplanned interaction. Employees, for their part, sometimes worried that their advancement would be compromised if they worked from home while most of their colleagues did not (Barrero et al., 2023; Nakrošienė et al., 2019).

COVID, of course, forced a change in these norms; many workers initially had no choice but to telework, and in the pandemic's aftermath much of the stigma or fear surrounding working from home had abated. More workers had permission to do more of their work remotely (Atkin et al., 2022; Barrero et al., 2023; Gibbs et al., 2023). There is little doubt, however, that the type of job, the norms surrounding remote work, are the major determinants of telework.

2.2.2 Telework, travel and the built environment

Once a worker has permission to telework, the built environment may become more relevant. Our expectation is that, controlling for occupations that allow remote work, the availability of parking will be associated with the decision to work remotely. Put simply: a person who must pay for parking at work, or who lacks parking at home, incurs greater costs in time and/or money by driving to work. Working from home is not the only way to reduce those costs (conceivably this person could also take transit), but it is one way to do so.

Assuming this person does choose to work from home, a second question is the extent to which that decision actually reduced household travel, particularly vehicle travel. During COVID, travel plunged while teleworking surged, but COVID was marked by economy-wide contractions; a lot of work went remote, but many other establishments closed as well (stores, gyms, restaurants, concert halls), and people were warned not to socialize. Some of the reduced travel that *coincided* with teleworking, in other words, may not have been *caused* by teleworking.

Indeed, in less restrictive pre-COVID circumstances, the existing evidence about telework and travel is mixed. Teleworking undeniably reduces commute driving (e.g., Hook et al., 2020) and that can be important, given that commute hours suffer from the most congestion and pollution. It is less clear, however, that telecommuting reduces driving overall, and indeed some evidence suggests that telework can make driving rise (e.g., Caldarola & Sorrell, 2022).

The reasons for this increase are varied. Telecommuting is sometimes associated with a greater distance from work. The causality of this association with longer distances is probably bidirectional: people are more likely to telework if they live far away, but also more likely to live further out if they have the option to telework. In either case, on days when teleworkers do drive in, their longer trips fully offset their not driving on other days. This logic implies that total reductions in driving are more likely if someone teleworks every day (e.g., they are fully remote and not hybrid), and some evidence suggests as much (Caldarola & Sorrell, 2022).

Less-frequent but longer commutes, moreover, are not the only reason telework could be associated with more driving. Telework could replace a transit commute rather than a driving one. If the teleworkers then make some non-work car trips (running errands or dropping kids at school), their vehicle miles travelled (VMT) could rise as their commute distance falls to zero. And regardless of the commute counterfactual, teleworking could increase non-work driving. This increase could occur because the teleworker gets "cabin fever" and drives to escape the house and/or to replace the lost social interaction that results from home-based work. It could also occur because having a vehicle at home (as opposed to parked at work all day) allows other members of the household to drive more (Kim et al., 2015; Lachapelle et al., 2018). The evidence, in summary, suggests that teleworking can reduce commute VMT, but will likely increase non-work VMT, although not always by enough to swamp the effect of reduced commute miles.

3 Data and method

Our primary hypothesis is that the price and availability of parking will influence people's travel behavior, including whether they telework, their modes of transport, and how much they travel. Specifically, we expect that people with free parking available at home or work will be more likely to drive (and drive more miles) and less likely to use transit, than people without. Our expectations surrounding the decision to work from home are more tempered: we anticipate that a lack of free parking at work will be associated with more remote work, but do not see a clear relationship between free residential parking and the decision to work from home. We expect occupational categories to explain more of the variance in working from home. We also have no strong prior about whether working from home will be associated with less total driving.

Our primary data source is the 2010-2012 CHTS. As we discussed in the introduction, the CHTS is a large travel diary, carried out on behalf of the California Department of Transportation and designed to be representative of California households. Its advantage, for our purposes, is the extent of its non-residential parking data. Alone among travel surveys, the CHTS records where a person parked for almost every trip away from home, and also records how much (if any) the traveler paid to do so. It also differentiates between on- and off-street parking. The presence of these detailed parking data, matched to both a travel diary and extensive socioeconomic information, is unique among transportation data sets.[4]

The CHTS has two potential drawbacks. The first, which we will discuss in Section 3.2, is a lack of reliable data on residential parking. The second, which we will discuss now, is that the data are by now rather old. For two reasons, we are not overly concerned with the CHTS's age. The first reason is that with one exception (telework), neither California's overall travel behavior nor its built environment have changed much since the CHTS was administered. The automobile and the single-family home remain dominant: Census American Communities Survey (ACS) data show that in 2011, 92% of California households owned vehicles, and detached single-family homes accounted for 59% of all occupied housing units; in 2022, the figures only changed slightly, to 93% and 58% respectively. Most neighborhoods, particularly in the expensive coastal metros where most people live and most economic activity occurs, have not seen their development densities change. The demographics of some coastal metropolitan statistical area (MSA) neighborhoods have changed substantially, often because housing prices have sharply risen, but these rising prices owe in many ways to the built environment remaining unchanged. Demand for housing rose but new housing was slow to be developed, so demographics changed rather than density.

Similarly, while statewide transportation policy has changed since the CHTS, it has not done so in a way that has changed behavior. Some California counties, Los Angeles in particular, have poured resources into public transportation, but these efforts have yielded little fruit: transit use in Los Angeles and much of the state were falling from 2013 forward (Manville et al. 2023; Schouten et al., 2021). And while California approved a landmark parking reform bill in 2023, which restricted the ability of local governments to require parking, that bill is likely to change the state's built environment very slowly, given that parking requirements have been in place in most of the state for decades. A few California cities have also started to use demand pricing to manage street

[4] The recently released 2022 NHTS records if a person paid for parking on the travel day and for each trip, and how much is paid for parking, but it does not record where the vehicle was parked.

parking, with Los Angeles' Expresspark and San Francisco's SFpark being the main examples. Nevertheless, California still has an abundance of government-mandated off-street parking and underpriced street parking too.

The major exception to the reasoning above is working from home: it is much more prevalent now than when the CHTS was administered. ACS commuting data show that in 2011, across California counties, 4.4 percent of workers worked from home. In 2022 that figure had more than quadrupled, to 17.3 percent. It seems probable, however, that this change is almost entirely a product of COVID and its impact on workplace norms, not a result of California's changing built environment. The ACS also shows, for example, that in 2019, only 6 percent of workers worked from home—quite similar to 2011. The CHTS obviously does not capture the change in workplace norms that helped unleash teleworking, but norms are not one of our variables of interest. Our questions revolve around the built environment's impact, controlling for norms, and the built environment (again) has not changed much.

Our second reason for not worrying much about the age of CHTS data is more general. Our goal in this paper is to test a broad idea—that people with less access to parking will, ceteris paribus, be less likely to drive. It is a truism in research that a good test with older data is better than a bad test with newer data. If the research we undertake here demonstrates that parking availability and price were strongly associated with travel behavior in California in 2010-2012, that finding will have academic and policy relevance so long as Californians in those years were responding to their built environment in the way that most people will, in most places at most times. We have no reason to believe this is not the case.

3.1 Dependent variables

Our interest lies in the association between parking availability and three main travel behaviors: the decision to work from home, the choice of commute mode, and the amount of overall travel by car and transit. We measured these at both the individual and household level.

Our ability to measure these variables differs somewhat by question. For employees who travel to work, the CHTS reports data on 29 different commute modes. We collapsed and then built two variables for the travel we are interested in: commuting by transit and commuting by driving. To create VMT variables, we used CHTS data on the mode and distance of individual trips. We summed car and transit trips at the individual and household levels, and then summed car trip distances to compute total VMT. The variables themselves are twofold: a binary variable indicating whether an individual drove, took transit, etc., and then a proportional variable showing the share of workers in the household who did so.

Our most problematic variable is the measure of telework. Telework is a dependent variable in some regressions, and an independent variable of interest in some others (when we examine the idea that working from home reduces VMT). The major data constraint for analyzing remote work is that work location is rarely tracked directly; we learn about it instead as a byproduct of questions about commuting. In the US Census, for example, working from home appears only as a choice when respondents are asked about how they travel to work. The CHTS is similar: for employed respondents, the CHTS provides data on work location. These data are coarse: they show if an individual's job location was fixed (such as at an office), if it was at home, or if it varied (e.g., a salesperson who travels, or a construction worker who goes to different job sites). Given this breakdown, we cannot know if people working from home were working at home in a home-based business, or working remotely from home for an office-based job. As a result, our work from home variables are highly imperfect proxies for telework; they capture not just telework but also other forms of home-based employment. As we discuss below, the built environment may influence these two forms of home-based work differently. As with our other dependent variables, we constructed work from home variables for both individuals and households.

This approach presents a problem, because not all home-based work is remote work. Remote work (or telework), at least in the sense it is commonly used, involves a job that has a fixed location outside the home, but that the employee performs from the home instead, all or part of the time. Remote work of this sort is what increased dramatically during COVID-19 (Brynjolfsson et al., 2020); lawyers, bankers and other people who were normally in offices were suddenly laboring from their kitchen tables.

Much work from home, however, is *not* telework, and instead involves people working or running businesses from their housing units, without any fixed location elsewhere. Examples can include freelance writers and artists, accountants who work from home offices, and people who give piano lessons or haircuts from their houses (Letourneux & Schütz, 2022). Data sets that ask only if someone works from home, as most large data sets do, are accurate insofar as they capture the absence of a commute, but make it difficult to differentiate within that absence, and distinguish between telework and home-based work.[5]

Distinguishing between these categories is important, however, because they have different implications for travel, and for how the built environment might influence it. A telecommuter represents a foregone work trip. A work-from-home business owner or entrepreneur may not—either because they regularly drive for work to have meetings, or because, if they could not work from home, they may not work at all (e.g., a parent who can watch a child while running a home-based business, but not while working in an office).

For our purposes, moreover, telecommuting and home-based work might have different associations with the built environment. Telecommuters may be more likely to stay home if parking near the home is hard to find: going to work might invite the hassle of searching for parking when they return. Piano teachers, in contrast, might be more likely to teach from home if parking near the home is easy to find—ease of parking could help attract and keep customers. Unfortunately, the CHTS data does not allow for distinguishing between working *from* home and working *at* home, which undermines our ability to tease out how parking relates with telework.

Because we cannot know if people working from home were working at home in a home-based business, or working remotely from home for an office-based job, our work from home variables are highly imperfect proxies for telework. These variables capture not just telework but also other forms of home-based employment.

3.2 Independent variables of interest—parking availability

We constructed binary variables indicating if a household had bundled parking at home and whether an individual employee had free parking at work. We built the work parking variable from CHTS data about the price and availability of parking at various trip destinations. We identified trips ending at the respondents' workplace, and then coded that commute as having free parking if the parking was either unpriced, or if it was priced but employees were reimbursed by employers. An important limitation here is that

[5] Some of these people may work outside the house (a writer might go to a coffee shop) but the Census would most likely still record them as working from home for commuting purposes.

the CHTS only shows the availability of free parking at work if the employee travels to work on the survey day. As such, we cannot directly test the idea that free parking at work is associated with less telework.

The home parking variable is more complex. As we mentioned briefly above, the CHTS, somewhat surprisingly, does not contain usable information about residential parking. We overcome this problem by combining CHTS data with data from the American Housing Survey (AHS). The AHS reports the presence of bundled residential parking, and the 2011 AHS overlaps the CHTS in both time and geography. As such, we can use the AHS to estimate the probability that a housing unit in the CHTS had bundled parking.[6]

Our procedure for doing so was as follows. The AHS shows if a housing unit has off-street parking included in its rent or purchase price, with off-street parking defined as a garage or carport, driveway, or other off-street parking. We defined housing units that include one of these options as having bundled parking. We then used this tabulation as the dependent variable in a series of logistic regressions, and predicted the presence of bundled parking with independent variables that were available in both the AHS and CHTS. These included the structure type (e.g., apartment, detached single family home), household size, tenure, and center city location, and—for units in metropolitan areas—MSA fixed effects. The regression took the following form:

$$\text{Bundled parking} = \alpha + \beta 1 * \text{central city} + \beta 2 * \text{MSA} + \beta 3 * \text{household size} + \beta 4 * \text{housing structure type} + \beta 5 * \text{owner occupied} + \varepsilon$$

We estimated separate regressions for units inside and outside MSAs (See appendix for model results). For units within larger MSAs, we used the AHS metropolitan surveys, which offer representative samples of each MSA's housing stock. For units in smaller MSAs, we relied on data from the AHS national data, which has smaller samples. For units outside MSAs, we predicted bundled parking from the Pacific and Mountain West regional sample of the national AHS data (there were no MSA variables in this model).[7] Our estimates will thus be most representative in the largest MSAs where most Californians live (and where travel behavior is most varied) and least representative in rural areas. We validated our model using a subset of the AHS data and found that the model predicts bundled parking relatively well.[8]

We used the parameters estimated from these models to predict the probability that households in the CHTS had bundled residential parking. For simplicity, in most cases

[6] This general approach, of predicting a variable in one data set based on a model constricted in another, is similar to the procedure described in Manville et al. (2023) for inferring transit ridership from the US Census.

[7] To be more precise: the AHS metropolitan sample offers representative detail of core California MSAs, including Los Angeles-Long Beach, San Diego, San Francisco, Oakland, San Jose, Sacramento, Anaheim-Santa Ana, and Riverside-San Bernardino. The AHS national sample contains those major MSAs and 9 additional: Bakersfield, Fresno, Modesto, Oxnard-Ventura, Salinas-Seaside-Monterey, Santa Barbara-Santa Maria, Santa Rosa-Petaluma, Stockton, Vallejo-Fairfield-Napa. We aggregate these into a California MSA sample and generate a parking probability for units in these MSAs, and then use regional data from the national sample to generate probabilities for housing units outside metropolitan areas.

[8] We split the AHS sample into a training subset (75% of all observations) to fit the model, and a testing subset (25% of all observations) to validate it. We calculated the Area Under the Receiver Operating Characteristics curve of the model for both subsets, and got high and very close values (0.88 and 0.89). This indicates that our model fits the data well.

we converted the predicted probability into a binary variable (1= bundled parking present, 0 = otherwise). We did so using cutoff values that yielded roughly equal rates of false positives and false negatives when we examined the AHS data.[9] A drawback of the AHS variable is that it does not indicate how many spaces are present at the housing unit, only that at least one is there. The AHS is also a measure of bundled parking. It tells us that the price of the housing unit includes a parking space. It does not indicate if parking is available on-site for an additional fee.

Constructing this variable gave us binary measures of both parking at home and parking at work. We then tested the association between parking availability on people's travel behavior. We regressed bundled parking at home on the dependent variables—working from home, commuting by transit, commuting by driving, total number of transit trips, total number of car trips, and total VMT, and in addition, free parking at work on the two commuting variables. We estimated all the models at both individual and household levels. For the regressions estimating the total number of car trips and total VMT, we also estimated models restricted to households with employed workers.

The functional form of our regressions varied with our dependent variables. For binary variables such as teleworking, commuting by transit, and commuting by driving and the fractions computed for household level analysis of these variables, we fitted logistic models; for count variables like total number of transit trips and total number of car trips, we fitted negative binomial models; for total VMT, which is left censored, we fitted a Tobit model.

3.3 Control variables

We controlled for an array of factors likely to influence travel behavior. Perhaps the largest of these is vehicle access. Parking availability can influence travel behavior directly, by increasing the probability that a person drives for any given trip, but also indirectly, by influencing the probability that they have an automobile. The second channel is likely larger than the first; previous research suggests a strong causal relationship between residential parking and the decision to own a residential vehicle (Manville 2017; Millard-Ball et al. 2022). We document this relationship in an initial regression (see Section 4.2) that uses vehicle ownership as a dependent variable, but our primary interest is in the second channel: the relationship between parking changes and travel behavior even controlling for vehicle ownership. We also controlled, in a similar vein, for the number of licensed drivers in the household.[10]

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[9] We experimented with different cutoff values to define the binary variable and compared them to the observed bundled parking variable from AHS data. We chose the values (one for inside MSA and one for outside) that generated similar rates of false positives and false negatives to balance between the possibility of over- and under-estimating parking availability for the CHTS sample. For example, the cutoff value we chose for inside MSA, 0.945, yielded 19% false positive and false negative rates. A higher value of 0.95 would yield 17% false positive and 21% false negative rates; while a lower value of 0.94 would yield 20% false positive and 18% false negative rates.

[10] Arguably both household vehicle access and licensure are endogenous to travel decisions. This endogeneity threat is larger, however, at larger scales of spatial and temporal aggregation. Measuring the prevalence of vehicles and licenses at a neighborhood scale and associating that prevalence with driving raises obvious issues of simultaneity. Similarly, examining a person's travel habits over a year and then correlating that with licensure and vehicle ownership does the same. Examining the factors within a daily travel diary, in contrast, poses fewer problems, particularly when they are controls, rather than the variables of interest. A person's decision between modes for a given trip hinges in part on the ability to access some of those modes, and isolating the association between this decision and parking *without* capturing the presence of cars or licensure would likely bias the parking coefficient.

We controlled for built environment characteristics. Research on the so-called "Five Ds"—density, diversity, design, destination accessibility, and distance to transit—suggests that the built environment can affect people's travel behavior, although the extent of this influence remains a source of debate (Ewing & Cervero 2017, 2010; Stevens, 2017). We measured built environment attributes using neighborhood typology data developed by Voulgaris et al. (2017). Voulgaris et al. collected 2010 data on 20 different measures of census tract-level built environments, including measures of density, transit service, job access, and street layouts. They then used factor and cluster analyses to categorize census tracts into seven distinct neighborhood types. Of most relevance to our work is their finding that most neighborhood types differ little from each other in their travel behavior, but that one comparatively rare type, which they call "Old Urban," accounted for a highly disproportionate share of non-auto travel. Old Urban neighborhoods are what they sound like: dense, largely multifamily census tracts with tight street grids and reliable transit service. Because the CHTS has census tract identifiers for each respondent, we were able to merge the neighborhood typology with the CHTS data, and used the neighborhood variable to control for built environment characteristics. We expect Old Urban neighborhoods to have less off-street parking, but also hypothesize that parking will be associated with travel behavior even controlling for neighborhood typology.[11]

We controlled for socioeconomic characteristics. All regressions included data on race, gender, age, disability status, nativity, income, and educational attainment. We did not include controls for tenure and the number of units in the housing structure, because these were the biggest predictors of residential parking, and including them created multicollinearity. All models included some form of county fixed effects.

Some models called for additional controls. The regressions analyzing people's decision to work from home included CHTS variables indicating respondent occupation, as well as a binary indicating if the respondent had a flexible work schedule (defined as being mostly free to adjust their schedule as they like). The occupation variables are not fine-grained (e.g., the "education" category cannot differentiate between a school teacher, a piano teacher, and a professor) but do let us control, albeit roughly, for the type of work a respondent does. The work from home regressions also included a rough proxy for broadband access. The CHTS includes no data on respondent access to high-speed Internet, so we used county-level data from the 2013 ACS on the proportion of working age population with access to broadband. In addition to measuring regional broadband access, these variables can essentially function as county fixed effects, so in the work from home models we omitted explicit county fixed effects.[12]

Our commuting models controlled for distance to work. Arguably this variable is endogenous: people might drive because they live far from work, but they might take a job farther away because they know they can drive. Most of this endogeneity, however, would relate to car ownership rather than parking availability. People who knew they would live far from work would be more likely to buy a car, and people who buy cars may be more likely to take jobs far from work. Lastly, for our models examining the total number of transit and car trips and total VMT, we included employment status as an

[11] Parking is not one of the components of the neighborhood typology used by Voulgaris et al.

[12] In the work from home regressions, some of the standard control variables also take on additional meanings. Income's association with working from home is probably partly the result of income being a proxy for managerial or knowledge-work, partly it being a proxy for having more space, and partly the result of higher-income households, due to marginal tax rates, preferring the convenience of working from home to extra pay.

additional control. Table 1 shows all our variables and their sources.

Table 1. Variables used in analysis

Dependent variables	Source
Work from home ^	CHTS
Commute by transit ^	CHTS
Commute by driving ^	CHTS
Total number of daily transit trips	CHTS
Total number of daily car trips	CHTS
Total daily VMT (distance traveled by car)	CHTS
Independent variables	
Bundled parking at home (binary)	AHS, CHTS
Free parking at work ^	CHTS
Controls	
Neighborhood typology	Voulgaris et al. (2017)
Distance to work	CHTS
Flexible work schedule ^	CHTS
Occupation	CHTS
Share of county population with broadband access	ACS
Number of household vehicles	CHTS
Number of licensed drivers in household	CHTS
Household income	CHTS
White ^	CHTS
Black ^	CHTS
Asian ^	CHTS
Latino ^	CHTS
Male ^	CHTS
65 or over ^	CHTS
Disabled ^	CHTS
Foreign born ^	CHTS
Employed ^	CHTS
Bachelor's degree or higher ^	CHTS
Less than high school ^	CHTS
County fixed effects	CHTS

Note: ^ These variables are expressed as binaries for regressions examining individual travel behavior, and expressed as fractions of the household for regressions examining household travel. For variables that apply to employed individuals only, the fractions are out of the total number of household workers.

4 Results

4.1 Descriptive results

Before turning to our regressions, we take advantage of the relatively rich data the CHTS offers, and paint a picture of California's parking and travel landscape in 2010-2012. Table 2 shows that across the sample, driving was the predominant travel mode. Mean and median daily household VMT were only slightly lower than those of daily household person miles traveled (PMT), suggesting that travel was overwhelmingly by car.[13] The middle rows of the table examine VMT's relationship with work location. We

[13] These VMT and PMT numbers differ only slightly from those from the California oversample of the 2017 NHTS. Mean and median VMT for California in the 2017 NHTS are 45 and 24, and mean and median PMT are 93 and 36.

see that the small share (about 9 percent) of households with a worker who worked from home did in fact average less daily driving than those who commuted to a fixed work location. Daily VMT in these work from home households had a mean of about 40, and a median of about 20, compared to a mean and median of about 53 and 26 for households where workers had a fixed location. Households where at least one worker had a varying work location had VMT roughly equal to work-from-home households, but were also very small in number (less than 1 percent of the sample).

The table's final rows illustrate the rarity of transit use in California. While the average household took over 8 trips per travel day, it took only 0.3 trips by transit. The median number of daily transit trips and the median share of trips that used transit were both zero.

Table 2. Summary of daily household (HH) trips (source: CHTS)

	N	mean	sd	median
Total VMT	42,421	66.4	136.7	30.1
Total PMT	42,421	86.9	385.1	34.1
Total VMT for HHs where a worker works from home	3047	40.4	112.1	19.9
Total VMT for HHs where a worker has a fixed work location	31950	52.6	89.6	26.0
Total VMT for HHs where a worker has a varied work location	376	39.6	66.2	17.5
Total trips	42,421	8.3	7.8	6
Total transit trips	42,421	0.30	1.3	0
Fraction of HH trips that are transit	36,735	0.03	0.09	0

Table 3 turns more specifically to commuting, which—while important because of its association with congestion—accounts for a relatively small share of both household and individual travel. Commuting can be examined in two ways: via individual trips (what share of trips are commutes?) or individual travelers (how does the typical person commute?). Table 3 examines trips. We see that, on average, only 16% of all household trips were commutes (this percentage rises slightly, to 19%, if the sample is restricted to households with at least one worker). Almost 88 percent of commute trips were completed by driving alone. Another 6.8% were carpool, just over 5% by non-motorized modes like walking and biking, and less than 0.3% by transit. Commutes tended to be long; they were 16 percent of household trips but accounted for 22 percent of household VMT on average. The average driving commute trip was 29 miles,[14] and the median 17 miles.[15]

[14] A large share of commutes in the sample involve a trip-chain. On average, 45% of a household's commute trips involved quick stops. The CHTS does not detail what these stops were: they could be visits to drive-through businesses or retail, dropping off passengers, or (for people on transit) transfers. The prevalence of trip chains could help explain the appeal of driving, but driving—because of the flexibility it enables—could also explain the prevalence of trip chaining. (If people did not drive, they would make the trip on its own).

[15] If we examine travelers rather than trips, we see similar proportions: 83% of respondents reported driving alone as their mode of commuting, and only 6% reported transit as mode of commuting (4.7% for walking and biking, 5.3% for getting rides from other people).

Table 3. Summary of household (HH) commute trips (source: CHTS)

	N	mean	sd	median
Fraction of HH trips that are commute	36,735	0.16	0.28	0
HH VMT for commute	15,070	29.1	37.3	18.1
HH PMT for commute	15,826	28.3	36.9	17.3
Fraction of HH VMT that is commuting	34,246	0.22	0.34	0
Fraction of HH PMT that is commuting	36,641	0.20	0.32	0

Note: VMT measures only count car trips and hence exclude households that only used non-auto modes. The latter households were included in PMT calculations. Because non-auto trips tend to be shorter, household PMT measures have slightly smaller means and medians than household VMT measures.

Table 4 turns to our main variable of interest: parking. By our estimate, the vast majority of sample households (87.9%) had bundled parking at home. Similarly, 79.2% of employed people had free parking at work. Away from home and work, parking was still abundant and often free or very inexpensive. Most trips in our sample required parking: only about eight percent of trips ended with the driver not leaving the vehicle, suggesting a drop-off, or a driver waiting while a passenger did an errand. The vast majority of trips that required parking ended in free parking off street. For the average person in the sample, only about 9 percent of daily trips that required parking used a street parking space, and fewer than one percent (0.37%) of these people paid for that street parking. The remainder of the people that parked did so off street. On average, 99% of an individual's daily trips ended with free parking.

Table 4. Descriptive statistics on parking

	N	mean/%	sd	median
Fraction of households w/bundled parking (estimated) at home	38,679	87.9%		
Fraction of employees w/free parking at work	26,341	79.2%		
Fraction of trips that involve leaving the vehicle	73,406	0.92	0.21	1
Fraction of trips where parking was free	48, 505	0.99	0.09	1
Fraction of parking that was on street	48,615	0.09	0.23	0
Amount paid to park on travel day	111,976	0.10	5.6	0
Amount paid to park (if > $0)	891	6.3	11.3	2.6
Total time a car is parked (hours)	48,150	22.6	1.4	23.0

Notes: Calculated from the CHTS & AHS. Calculations shown are averages for individuals. Household level calculations households show similar results.

Notably, among the minority of people who paid to park (less than 1 percent of the sample) the average daily payment wasn't trivial: $6.33.[16] The median, however, was much lower, at $2.60, suggesting that parking costs are Pareto-distributed and highly concentrated. A small proportion of the 1 percent of travelers who paid to park accounted for most of the payment. The table's final row, meanwhile, shows parking's enormous temporal demands. The average car in the sample was parked almost 23 hours per day.

The sheer amount of time vehicles were parked suggests parking's potential to influence travel decisions. Table 5 reinforces that impression. Almost 95% of employed people with free parking at work reported commuting by automobile, while just under 37 percent of people without free work parking did the same. Most people without free

[16] By way of comparison, a gallon of gas in California 2010-2012 averaged between $3.00 and $3.74 in nominal dollars, meaning the average daily parking price was close to double the average per gallon fuel cost.

parking at work rode transit (27.6%), walked or biked (18.7%) or carpooled with others (15%).

Table 5. Commute modes for individuals who commute, with and without free parking at work (source: CHTS)

	N	Driving alone	Transit	Walk/bike	Get rides	Other
With free parking	17,906	94.5%	0.92%	1.4%	2.5%	0.71%
Without free parking	4,682	36.9%	27.6%	18.7%	15%	1.9%

Although not shown in the table, parking's prevalence is correlated with neighborhood typology. Parking is much scarcer in Old Urban neighborhoods described by Voulgaris et al. (2017). While only a small share of our respondents (6.5%) lived in Old Urban neighborhoods, these households accounted for 46% of units without bundled residential parking (See Appendix Table A1 for distribution and density of neighborhood types). They also accounted for 22% of total transit trips and over 24% of zero-vehicle households. Most of these neighborhoods are in Los Angeles and San Francisco counties, and they are notable for their high average tract density: almost 25,000 people per square mile. Even in these neighborhoods, however, our estimates suggest that most households still had bundled parking at home (67%), and most still owned cars (78.1%).

4.2 Regression results

Our first set of regressions, with household vehicle ownership as the dependent variable, yields results consistent with previous research: bundled parking (estimated) at home is associated with more household vehicles (Table 6). This relationship is robust to an array of controls, including household income and the presence of more licensed drivers. Specifically, having free parking at home is associated with owning 0.23 more vehicles in a household, other factors held constant.

To put the size of this association into perspective: The average marginal effect of having bundled parking at home is 0.42 more household vehicles, smaller than the marginal effect associated with an additional licensed driver (0.56), but larger than effects associated with even fairly large jumps in household income. Moving from one income category to another is associated with 0.05 to 0.25 more vehicles. While the association we find between residential parking and vehicle ownership is not causal, the reported magnitudes are similar to those found in instrumental variable approaches (Manville, 2017) and quasi-experimental approaches (Manville, 2017; Millard-Ball et al. 2022).

Recall that we predicted bundled parking using variables like household size, structure type, and home tenure. A reasonable concern is that these variables are correlated with household income, and that our bundled parking coefficient is simply detecting income effects. We address this concern in Table 6's second regression, which omits the parking variable. In its absence the income coefficients do grow, but only slightly. We are reassured by this result. Housing with bundled parking tends to be more expensive than housing without it (Gabbe & Pierce, 2017; Manville, 2013), so its presence will be mildly correlated with income, but the key point is that cities require almost all housing to have parking at the time they are built. Many housing units as a result come with parking when they are initially expensive, but still have parking as they filter down and become occupied by lower income people. We believe, for this reason, that our parking coefficient is largely picking up an association with parking itself, not income or wealth.

Table 6. Association between parking and vehicle ownership (negative binomial regression)

	Number of household vehicles	Number of household vehicles
Bundled parking at home (estimated)	0.23 ***	
	(0.02)	
No. of licensed drivers	0.30 ***	0.31 ***
	(0.00)	(0.00)
Household income: 10,000 – 24,999	0.19 ***	0.20 ***
	(0.03)	(0.03)
Household income: 25,000 – 34,999	0.33 ***	0.36 ***
	(0.03)	(0.03)
Household income: 35,000 – 49,999	0.38 ***	0.42 ***
	(0.03)	(0.03)
Household income: 50,000 – 74,999	0.46 ***	0.50 ***
	(0.03)	(0.03)
Household income: 75,000 – 99,999	0.49 ***	0.53 ***
	(0.03)	(0.03)
Household income: 100,000 – 149,999	0.52 ***	0.56 ***
	(0.03)	(0.03)
Household income: 150,000 – 199,999	0.54 ***	0.59 ***
	(0.03)	(0.03)
Household income: 200,000 – 249,999	0.57 ***	0.62 ***
	(0.04)	(0.04)
Household income: 250,000+	0.60 ***	0.65 ***
	(0.04)	(0.04)
Socioeconomic status controls	Y	Y
Neighborhood controls	Y	Y
County fixed effects	Y	Y
Constant	-0.86 ***	-0.74 ***
	(0.04)	(0.04)
Observations	35,716	35,800
AIC	95574	95944

Notes: Significance codes: ***p < 0.001,**p < 0.01, *p < 0.05; Standard errors in parentheses. Socioeconomic status controls include race (Asian, Black, Latino), male, 65 or older, foreign born, disabled, employed, household income, Bachelor's degree or higher, less than high school; Neighborhood controls are neighborhood typologies from Voulgaris et al. (2017), only neighborhoods of home locations used; County fixed effects are counties of home location; Y indicates the controls are included in the model.

In our second set of regressions we turn to travel mode choice (Table 7). Vehicle ownership, in these and all subsequent regressions, becomes a control variable. We see that our bundled parking variable is associated with fewer daily transit trips, for both individuals and households. Specifically, having free parking at home is associated with 0.55 fewer daily transit trips for individuals and 0.45 fewer for households, ceteris paribus. The magnitude of the association is comparable to that of the relationship between transit use and adding an additional household vehicle (0.56 fewer daily transit trips for individuals and 0.53 for households). Expressed as average marginal effects, bundled parking is associated with 0.07 fewer daily transit trips for individuals and 0.16 fewer household trips. Both of these are slightly smaller than the effect associated with an additional vehicle (0.09 and 0.19). The association is robust to controlling for an array of demographic and built environment factors, including household vehicles, neighborhood typology, and licensed drivers.[17]

Table 7. Association between parking and transit trips (negative binomial regression)

	Total no. of transit trips on travel day	
	Individual	**Household**
Bundled parking at home (estimated)	-0.55 ***	-0.45 ***
	(0.07)	(0.08)
No. of household vehicles	-0.56 ***	-0.53 ***
	(0.03)	(0.04)
No. of licensed drivers		0.32 ***
		(0.04)
Employed	0.04	0.05
	(0.05)	(0.07)
Socioeconomic status controls	Y	Y
Neighborhood controls	Y	Y
County fixed effects	Y	Y
Constant	0.69 ***	0.22
	(0.17)	(0.18)
Observations	79,554	35,716
AIC	37344	33984

Note: See Table 6 notes for significance codes and controls.

Our third and fourth sets of regressions (Tables 8 and 9) turn to commute modes. Here the coefficients on bundled residential parking (estimated) are small and statistically insignificant. What matters instead, perhaps unsurprisingly, is having free parking at work. In all specifications, free work parking is statistically and economically associated with choice of commute mode. Specifically, individuals with free parking at work have about 87% lower odds of commuting by transit, and 22 times higher odds of commuting by driving; household level effects have the same direction but smaller magnitudes. These associations are substantially larger than those associated with having an additional household vehicle—the odds are 33% lower and 40% higher respectively. The household level associations have the same direction, but larger magnitudes.

[17] The positive association between number of licensed drivers and total daily transit trips may seem odd, but since the regression also controls for vehicles the coefficient reflects the number of licenses net of the number of cars, meaning that it largely reflects circumstances where a household has more drivers than cars. In these circumstances transit use becomes more likely (Manville et al. 2023).

Table 8. Association between parking and commuting by Transit (logistic regression)

	Using transit to commute			
	Individual		Household	
	Logit	**Odds ratio**	**Logit**	**Odds ratio**
Bundled parking at home (estimated)	0.07 (0.21)	1.1	-0.03 (0.18)	0.97
Free parking at work	-2.0 *** (0.14)	0.13	-1.7 *** (0.13)	0.18
No. of household vehicles	-0.41 *** (0.08)	0.67	-0.64 *** (0.09)	0.53
Stopped during the commute	-1.4 *** (0.18)	0.24	-0.36 * (0.15)	0.70
Distance to work	0.00 (0.00)	1.0		
No. of licensed drivers			0.23 ** (0.08)	1.3
Socioeconomic status controls	Y		Y	
Neighborhood controls	Y		Y	
County fixed effects	Y		Y	
Constant	0.34 (0.53)	1.4	-0.30 (0.47)	0.74
Observations	17,608		12,165	
AIC	2364		1748.6	

Notes: See Table 6 for significance codes and controls. Neighborhood controls in these regressions include neighborhoods of both home and work locations.

Table 9. Association between parking and commuting by driving (logistic regression)

	Driving to commute			
	Individual		Household	
	Logit	**Odds ratio**	**Logit**	**Odds ratio**
Bundled parking at home (estimated)	0.00 (0.10)	1.0	-0.04 (0.11)	0.96
Free parking at work	3.1 *** (0.06)	22.5	2.6 *** (0.07)	12.8
No. of household vehicles	0.31 *** (0.03)	1.4	0.51 *** (0.05)	1.7
Stopped during the commute	0.13 (0.13)	1.1	-0.29** (0.09)	0.75
Distance to work	0.01 *** (0.00)	1.0		
No. of licensed drivers			-0.26 *** (0.04)	0.77
Socioeconomic status controls	Y		Y	
Neighborhood controls	Y		Y	
County fixed effects	Y		Y	
Constant	-2.3 *** (0.39)	0.11	-1.38 * (0.29)	0.25
Observations	17,608		12,165	
AIC	9034.3		8645.6	

Notes: See Table 6 for significance codes and controls. Neighborhood controls in these regressions included neighborhoods of both home and work locations.

Our fifth and sixth sets of regressions examine overall auto travel—the fifth analyzes VMT (Table 10) and the sixth the number of daily car trips (Table 11). Results from both sets of regressions show that parking availability is associated with more auto travel. Specifically, Table 10 shows that having free parking at home (estimated) is associated with 6.6 more daily vehicle miles traveled by individuals, ceteris paribus, 14.6 more by households, and 12 more by households with employed workers. Free parking at home is also associated with 0.08 more car trips per day taken by individuals, 0.14 more by households, and 0.13 more by households with employed workers. Moreover, having free parking at work is associated with 10.4 more vehicle miles traveled and 0.1 more car trips taken by households with employed workers, ceteris paribus.

These magnitudes are not trivial: as Table 2 showed, the sample mean for household VMT is 66, so bundled residential parking's association with VMT is over 20 percent of the sample mean. It is also larger than the association between VMT and an additional household vehicle. The average marginal effect associated with bundled residential parking at home is 4.6 VMT for individuals, 11 for households, and 10.4 for households with employed workers. These figures for an additional vehicle are 2.4, 7.5, and 7.0 respectively. Similarly, for the number of daily car trips, the average marginal effect associated with bundled parking at home are 0.23 trips for individuals, 0.94 for households, and 0.97 for households with employed workers. For additional household vehicles those figures are 0.12, 0.44, and 0.3 respectively.

Tables 10 and 11 also include a binary variable indicating if a household member works from home. The results here, consistent with some previous literature, suggest that working from home is associated with more rather than less driving and vehicle use. Specifically, working from home is associated with 6 to 10 more VMT per day, and about 0.1 additional vehicle trips. These coefficients, again, represent a combination of telework and home-based work, so they should be interpreted with caution.

Table 10. Association between parking and VMT (Tobit regression)

	Total VMT (by car) on travel day			
	Individual	**Household**	**Employed individuals**	**Household with employed workers**
Bundled parking at home	6.6 ***	14.6 ***	6.9 ***	12.0 **
	(1.1)	(3.3)	(1.4)	(3.9)
Working from home			5.6 ***	10.4 *
			(1.4)	(4.9)
No. of household vehicles	3.2 ***	9.4 ***	1.9 ***	7.8 ***
	(0.3)	(1.3)	(0.4)	(1.5)
No. of licensed drivers		30.4 ***		26.9 ***
		(1.4)		(1.6)
Employed	18.5 ***	20.6 ***		
	(0.65)	(2.8)		
Socioeconomic status controls	Y	Y	Y	Y
Neighborhood controls	Y	Y	Y	Y
County fixed effects	Y	Y	Y	Y
Constant	-42.2 ***	-140.0 ***	-27.1 ***	-118.7 ***
	(2.7)	(8.3)	(3.8)	(10.7)
Observations	79,554	35,716	47,450	27,853
Log-likelihood	-337010.6 on 87 Df	-191540.5 on 88 Df	-222543.8 on 87 Df	-159070.6 on 88 Df

Note: See Table 6 for significance codes and controls; Df: degrees of freedom.

Table 11. Association between parking and vehicle trips (negative binomial regression)

	Total daily car trips			
	Individual	**Household**	**Employed individual**	**Household with employed workers**
Bundled parking at home	0.08 ***	0.14 ***	0.07 ***	0.13 ***
	(0.02)	(0.02)	(0.02)	(0.02)
Working from home			0.11 ***	0.10 ***
			(0.02)	(0.03)
No. of household vehicles	0.04 ***	0.06 ***	0.02 ***	0.04 ***
	(0.00)	(0.01)	(0.00)	(0.01)
No. of licensed drivers		0.37 ***		0.34 ***
		(0.01)		(0.01)
Employed	0.22 ***	0.08 ***		
	(0.01)	(0.02)		
SES Controls	Y	Y	Y	Y
Neighborhood controls	Y	Y	Y	Y
County fixed effects	Y	Y	Y	Y
Constant	0.52 ***	0.22 ***	0.76 ***	0.43 ***
	(0.04)	(0.05)	(0.04)	(0.05)
Observations	79,554	35,716	47,450	27,853
AIC	345549	202157	215356	164708

Note: See Table 6 for significance codes and controls.

Our final set of regressions uses work from home as the dependent variable. The results (Table 12) suggest that parking availability may have a small influence on the decision to work from home. Individuals with bundled residential parking (estimated) have about 14% lower odds of working from home. In comparison, individuals with an additional vehicle in the household have slightly higher odds (about 10% more) of working from home. In theory, the availability of free parking at work should be a stronger predictor of working from home, but recall that we cannot see this variable for people who work from home. The descriptive results in Table 5, however, along with a number of the regression results above, show that workers without free parking at work tend not to drive, so we have some reason to think the relationship between parking and working from home would be similar. In the data we have, the strongest predictors of working from home are having a flexible working schedule, broadband access, and education level.

In an additional analysis (not shown), we tested the differential effects on the association between bundled parking and working from home among urban, suburban, and rural areas. We found that bundled parking is significantly negatively associated with working from home for individuals in urban and suburban areas, but the association is positive for individuals in rural areas. The household model shows similar results, but the association for suburban households, while still negative, is not significant. These results could mean that the availability of residential bundled parking influences working from home decisions differently: it may discourage working from home in urban and suburban areas, but encourage working from home in rural areas.

Table 12. Association between parking and working from home (logistic regression)

	Working from home			
	Individuals		Household	
	Logit	**Odds ratio**	**Logit**	**Odds ratio**
Bundled parking at home	-0.15 *	0.86	-0.13	0.87
	(0.07)		(0.08)	
No. of household vehicles	0.11 ***	1.1	0.12 ***	1.1
	(0.02)		(0.03)	
Flexible work schedule	0.35 ***	1.4	0.19 **	1.2
	(0.05)		(0.07)	
Broadband access	1.6 ***	4.7	1.3 **	3.6
	(0.34)		(0.43)	
Bachelor's degree or higher	0.22 **	1.2	0.31 ***	1.4
	(0.05)		(0.08)	
Less than high school	-0.45 ***	0.64	-0.19 ^	0.82
	(0.13)		(0.12)	
Occupations	Y		Y	
Socioeconomic status	Y		Y	
Neighborhood type	Y		Y	
Constant	-4.8***	0.01	-3.7 ***	0.03
	(0.38)		(0.43)	
Observations	42,334		27,423	
AIC	20044		9173.1	

Notes: ^p<0.1.See Table 5 for other significance codes and controls; Flexible work schedule, broadband access, and occupations are added to working from home models as additional controls.

As discussed above, readers should be cautious about interpreting these last results. The work from home variable includes both people who work at home-based businesses and those who work remotely from home for an office job. The relationship between parking and travel for these two groups may be quite different. People who operate a home-based business may want parking, if they receive customers at their house. People who telework, in contrast, may do so because they lack home-based parking, or may choose a housing unit without parking because they telework. We cannot sort between these different mechanisms with our current variable, and as such treating our work from home variable as a proxy for teleworking will likely underestimate the true association between parking availability and people's decision to telework.

5 Conclusion

The aftermath of COVID-19, alongside growing awareness of the need to reduce internal combustion driving to meet environmental goals, has renewed interest in policies that might encourage people to drive less. Such policies might encourage more transit use or more teleworking. Much remains unknown, however, about the levers governments can pull to attain these outcomes, and indeed how these outcomes relate to each other. It is not clear, for example, that people who telework will drive less overall, even if they do not drive to work.

Because existing evidence does suggest that the price and availability of parking could impact all these outcomes, in this paper we use the CHTS to make two contributions. First, we use the survey's detailed parking data to present a heretofore unseen picture of how thoroughly parking, and particularly free parking, dominates the surface transportation system. Many observers have intuited that parking is a dominant part of the transportation system, but we are (at least to our knowledge) the first to put numbers to this intuition. Most trips are by automobile, most automobile trips end in a parking space, and most parking is free. Specifically: the typical California automobile spends over 22 hours per day parked, and virtually none of this time or space results in a direct cost for the driver.

This massive consumption of unpriced land and time implies a large subsidy for automobile use, and estimating the magnitude of its effect is our second contribution. Our raw data show that where parking is priced, driving is less common. Our regressions reinforce this impression, at both the individual and household level. Households with bundled residential parking are more likely to drive and less likely to use transit, both overall and for the commute in particular. We also show that these households drive more miles than other households. We find, similarly, that households where members with jobs have free parking at work will be more likely to drive to work, less likely to use transit, and more likely to drive more miles. All these relationships are robust to controls for vehicle ownership, driver's licensure, and an array of neighborhood-built environment and socioeconomic status characteristics. While we do not explicitly control for self-selection in our models, the existing literature suggests that, at worst, self-selection controls would only modestly reduce the magnitude of our findings, and might even increase them. We do not find a strong association between parking provision and working from home, but some of this null finding may stem from our imprecise controls for employment and occupation.

At a broad level, our results reinforce parking's role as an important intermediary in the relationship between transportation and land use. Given that both the abundance of off-street parking and the low price of street parking are often the result of local government decisions (Shoup, 2011), our findings can be seen as additional evidence in the case against off-street parking requirements, and against underpriced curb parking. The vast majority of the free parking we document occurs in off-street spaces, many of which, as previous research has shown, exist only because of government mandates (Shoup, 2011). Stopping the mechanism that forces these spaces into existence would not just make both transportation and land use more efficient, but could also make priced curb parking more feasible, and thereby deliver local government more revenue. Such reform cannot by itself make parking a more reliable and efficient municipal revenue source—the obstacles to this goal are numerous (Manville & Pinski, 2021)—but they will help.

Our results, again, are from older data, and they are only from California. As we have discussed, however, with the exception of work-from-home, there is little reason to think that the relationships we document from 2011 no longer hold in 2024. Similarly, we see little reason to think our results are unique to California. Much like the US overall, California has a combination of dense urban cores, extensive suburbs, and large swathes of rural areas. It is just one state, and that is a constraint, but studying California is not the same as studying Rhode Island. The built environments of California resemble the landscape of much of the urbanized United States.

With that said, there is certainly a strong need for newer data that covers more places. If such data had existed, we might not have relied on the CHTS. The recently released 2022 NHTS includes some parking variables and allows for a replication of our analysis at the national scale. Future research should seek to merge detailed parking data with more fine-grained data on work tasks and responsibilities. In a post-COVID world, travel surveys should do a better job of differentiating between telework and home-based work, and ask teleworkers what (if anything) parking would cost them if they chose to work in the office.

Future work should also address two questions we either only discuss, or examine only lightly: the question of whether teleworking reduces productivity, and the extent to which teleworkers drive less than other employees. Both of those questions speak to important tradeoffs embedded in the goal of promoting teleworking, which in turn have implications for teleworking's role in sustainable transportation.

Appendix

Appendix available as a supplemental file at https://doi.org/10.5198/jtlu.2025.2501.

Data availability

The github depository for data and scripts is available at https://github.com/haoding19/parking-and-travel-behavior-jtlu/.

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Author contribution

Research design, data analysis, manuscript writing: Hao Ding; study conception, research design, manuscript writing: Michael Manville.

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