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Residential Street Parking and Car Ownership

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A Study of Households With Off-Street Parking in the New York City Region

Zhan Guo

Problem, research strategy, and findings: Local governments' minimum street-width standards may force developers to oversupply, and residents to pay excessively for, on-street parking in residential neighborhoods. Such oversupply is often presumed to both encourage car ownership and reduce housing affordability, although little useful evidence exists either way. This article examines the impact of street-parking supply on the car ownership of households with off-street parking in the New York City area.

The off- and on-street parking supply for each household was measured through Google Street View and Bing Maps. The impact of on-street parking on car ownership levels was then estimated in an innovative multivariate model. The unique set-up of the case study ensures 1) the weak endogeneity between parking supply and car ownership and 2) the low correlation between off-street and on-street parking supply, two major methodological challenges of the study. Results show that free residential street parking increases private car ownership by nearly 9%; that is, the availability of free street parking explains 1 out of 11 cars owned by households with off-street parking.

Takeaway for practice: These results offer support for community street standards that make on-street parking supply optional. They also suggest the merits of leaving the decisions of whether, and how many, on-street parking spaces to provide in new residential developments to private markets rather than regulations.

Keywords: street standards, on-street parking, car ownership, Google Street View, New York City

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Parking policy has gained much attention over the past decade. This attention is partly due to the increasing emphasis on integrated transportation and land use planning and partly due to the gradual acceptance of Donald Shoup's (2005) critique of free parking. The two oft-cited parking problems are drivers cruising for on-street parking in urban centers (Arnott & Rowse, 1999; Shoup, 2006) and the minimum requirement for off-street parking (Cervero, Adkins, & Sullivan, 2010; Litman, 2004). Both are believed to contribute to increasing traffic congestion and auto dependency (Verhoef, Nijkamp, & Rietveld, 1995; Weinberger, Seaman, & Johnson, 2009), urban sprawl (Willson, 1995), degraded urban space (Mukhija & Shoup, 2006), and reduced housing affordability (Jia & Wachs, 1999; McDonnell, Madar, & Been, 2011). While resolving these two issues is the key to forming an efficient, effective, and equitable parking policy, this research addresses another important, but overlooked, parking problem. This problem is the minimum on-street parking requirements created by governments' minimum street-width standards.

Local governments commonly require a minimum street width in order to secure safe and efficient traffic flows. This requirement often includes dedicated parking lanes on one or both sides of a residential street. For example, the most common suburban residential street width is 36 feet, with two 8-foot wide parking lanes and two 10-foot wide traffic lanes (Southworth & Ben-Joseph, 1995). Because streets would be potentially wider if regulations allowed non-parallel parking (which can accommodate more parked cars), this minimum street width standard in conjunction with on-street parking is de facto a minimum requirement for on-street parking. The degree of required parking per unit would depend on the lot sizes along the street.

Critics have condemned modern street standards since their inception in the early 1900s. In 1910, Frederick Law Olmsted made a statement at the Second National Conference on City Planning in which he argued that "fixing a minimum width of street and minimum requirements as to the cross section and construction there of … make the cost needlessly high for purely local streets, and thus inflicts a wholly needless and wasteful burden of annual cost upon the people" (Olmsted, 1910). New urbanism and smart-growth advocates have called for skinny streets, but nonetheless often tolerate on-street parking on narrower streets (Ewing, Stevens, & Brown 2007; Neighborhood Streets Project Stakeholders, 2001).

Ignoring this parking requirement is worrisome because residential on-street parking makes up a large portion of the overall parking stock, and it seems overall to be a bad policy. In London, 3.2 million of the overall 6.8 million parking spaces consist of unlimited, on-street parking (Transport for London, 1999). The same ratio might hold in low-density developments, where on-street parking could easily match off-street parking. For example, the average number of garage spaces for a single-family home in the United States is 2.6,[1] while the average number of on-street parking spaces is between 4 and 5.[2] Most of these on-street parking spaces are free and considered as oversupplied because they add extra spaces to off-street parking stocks that are already criticized for being oversupplied. Visitors and commercial vehicles may occasionally use on-street spaces, but they mostly serve nearby local residents.

This artice is interested in how these free and oversupplied on-street parking spaces affect residents' travel and parking behavior. They are likely to increase the cost of housing and reduce the cost of parking. There are at least two possible impacts. First, residents may shift parking from off-street to on-street and then use off-street parking areas for other purposes, reclaiming housing space from parking. There is some evidence of such behavior. Coevering and Snellen (2008) found that many Dutch residents often underutilize their own private parking facilities, parking their car in a public spaces while using their driveways and off-street parking spaces for other purposes. Jenks and Noble (1996) surveyed 1,500 households in Lower Earley, near Reading, U.K., and found that 38% of single-car garages were not used to store automobiles, while 54% of two-car garages were used to store just one automobile. Other studies found similar results in other parts of the United Kingdom, wherein 56% of residential garages at various sites in England, 64% at Waterside Park and Kent, and 55% at various sites in Oxfordshire, were found not to be used for parking (Department for Transport, UK, 2007). In the United States, a survey of 97 open garages in the Mission District neighborhood in San Francisco showed that 49% were not used to store cars. Instead, they were converted to living rooms, photography studios, beauty salons, repair shops, etc. (Brown, 2007). In both the United States and the United Kingdom, many residents own cars and choose to park them on the street.

The second possible impact is for people to buy more cars than they would if on-street parking were unavailable or not free. This is understandable in terms of the principle that increased (free) supply induces more demand. However, the literature does not appear to contain any studies of this possible car ownership effect; therefore, this problem is the focus of this paper. Because on-street parking has a straightforward impact on car ownership for households without off-street parking, this research targets only those households that already have off-street parking (i.e., a garage or driveway).

This article is structured as follows. The second section discusses the analytical issues in capturing the on-street parking impact on car ownership. The third section describes the methodology, including data collection using Google Street and Bing Map, and the case study of the New York City region. The fourth section presents a series of car ownership models and analyzes results. The fifth section discusses policy implications, while the final section provides the conclusion.

On-Street Parking and Car Ownership: Analytical Issues

Identifying the size of distortion from a minimum quantity regulation could be challenging due to its binding effect. Studies on the effect of minimum wage on employment rate (Neumark & Wascher, 2006) and the effect of minimum lot size on housing price (Zabel & Dalton, 2011) have produced mixed results. For an analysis of the impact of on-street parking on car ownership, four specific challenges arise: 1) the endogeneity between residential parking and car ownership, 2) the high correlation between on-street and off-street parking, 3) the lack of off-street parking data, and 4) the measurement of the availability of on-street parking. The first two are methodological issues and the last two are data and measurement issues. This section discusses these challenges and proposes solutions to them.

Methodological Challenges

Endogeneity (challenge 1) refers to the fact that the relationship between parking supply and car ownership represents a typical relationship between supply and demand and could be mutually determined. Parking supply could constrain the demand for cars, but a preferred level of car ownership could also lead to the search for a residence to meet that demand. In the planning literature, this phenomenon is also known as self-selection (Handy, Cao, & Mokhtarian, 2006). Without controlling for this endogeneity, the estimation of parking supply on car ownership could be biased.

Off-street and on-street parking are often highly correlated (challenge 2). Larger lots tend to have larger garages and are associated with more on-street parking spaces. They also tend to neighbor each other on the same street. Therefore, residents living on large lots tend to have more cars while at the same time having access to more on-street parking spaces. This leaves an impression that abundant on-street parking encourages car ownership. If the two are perfectly correlated (multicollinearity), it is difficult to separate their effects on car ownership.

In order to break the high correlation and reduce the endogeneity, I target households with off-street parking in older urban settings such as the New York City. First, parking supply in such a setting is normally tight and has a relatively small variation. For example, most garages for single-family homes in New York City have just one space (80% in my sample). For households with a driveway but no garage, most (80%) have a driveway area for two cars (Table 1). This could help reduce the endogeneity between parking supply and car ownership since those households with off-street parking do not have many options from which to choose.

Second, in an older urban setting, the same type of residence may have different parking supplies, and different types of residences often coexist on the same street. For example, in New York City, a single-family detached home could have one of several parking situations: no off-street parking at all, only a driveway, a front garage without a driveway, or a backyard garage with a long drive alley. Meanwhile, a single-family detached home may neighbor a mid-rise apartment or a single-family attached home on the same street. Such a situation could largely reduce the high correlation between on-street and off-street parking.

During the data collection process, which I conducted through Google and Bing, I found many such situations in the New York City region. For example, in one case, the household only possessed a narrow, one-space driveway, but the neighboring households on the same street all had a private garage, making on-street parking uncrowded and available. Therefore, this household can own two cars and always park one of them on the street. In another case, the household had a private garage and a driveway, but most adjacent neighbors did not have off-street parking, including those in a five-story apartment building next door. On-street parking is crowded; the household owns only one car and probably does not park on the street due to the difficulty of finding a space.

I conducted statistical tests on the endogeneity and correlation in the sample. The two-stage least square (2SLS) models indicate that the endogeneity is weak (insignificant at the 10% level; see Appendix, Tables A-1 and A-2). The correlation between on-street and off-street parking variables is only –0.14. Therefore, the unique set-up of the case study largely solves the two methodological problems.

Measuring Residential Parking

Challenge 3 concerns missing off-street parking data. In the United States, local governments do not collect off-street parking information as long as developers meet a minimum requirement. Such a requirement often applies only to structured parking spaces like garages, but not to driveways or driveway alleys. Neither do local governments attempt to count the number of on-street parking spaces. The result is that nobody knows how many parking spaces are available to a particular household except the household itself. San Francisco has comes close: The city completed an on-street and commercial off-street parking inventory for only 35% of its neighborhoods (SFPark, 2010). In New York City, the tax lot database (PLUTO) records the square footage of structured parking area only for buildings with four or more housing units. The Certification of Occupancy database from the Department of Building records structured parking areas for all buildings in the city, but it is only available in floor plans, making it difficult to extract parking information.

The lack of data partly explains why residential parking research is missing in the literature. For example, although the importance of residential parking is acknowledged, this variable is largely absent in car ownership and residential location choice studies (Guo, 2004). For those that included a parking variable, a rough proxy, such as housing type (Chu, 2002; Giuliano & Dargay, 2006; Hess & Ong, 2002; Potoglou & Kanaroglou, 2008) or housing and job density (Ryan & Han, 2001), is usually used.

Challenge 4 is the measurement of on-street parking availability. On-street parking is public space not associated with any particular household, so its availability is subject to personal preference, government regulations, and social norms. For example, the number of spaces available to a household depends on how much search time is acceptable, as well as the walking distance between the parking location and the residence. Many cities prohibit overnight parking

Table 1. Descriptive statistics.

Variables		Mean	SD	Source
Household Attributes				
Car ownership		1.28	0.93	NYMTC Survey
Household Size		2.80	1.40	NYMTC Survey
Household income (scale 1–10)		5.02	1.93	NYMTC Survey
# of driver license		1.52	0.93	NYMTC Survey
# of workers (full + part time)		1.32	0.96	NYMTC Survey
# of children (≤ 17 years old)		0.64	0.95	NYMTC Survey
Single-family detached (yes/no)		0.52	0.50	NYMTC Survey
Single-family attached (yes/no)		0.25	0.44	NYMTC Survey
Apartment (yes/no)		0.23	0.42	NYMTC Survey
Household head Black (yes/no)		0.16	0.37	NYMTC Survey
Household head Hispanic (yes/no)		0.17	0.38	NYMTC Survey
Land use attributes				
Job density (per square mile in the zip code)		5,115	4,348	U.S. Census Bureau (2007)
Population density (per square mile in the block group)		37,386	23,204	U.S. Census Bureau (2010)
Network distance to the nearest train station (mile)		2.54	2.42	[a]
Entropy (within ½ mile buffer of residence)		0.49	0.21	[b]
Household live in North Manhattan (yes/no)		0.01	0.09	NYMTC Survey
Household live in Bronx (yes/no)		0.11	0.32	NYMTC Survey
Household live in Queens (yes/no)		0.21	0.41	NYMTC Survey
Household live in Brooklyn (yes/no)		0.25	0.44	NYMTC Survey
Household live in New Jersey (yes/no)		0.42	0.75	NYMTC Survey
Parking supply				
Off-street parking supply		2.00	1.18	Google and Bing
On-street parking crowding level (scale 1–8)		5.94	1.82	Google and Bing
Total number of observations			403 households with off-street parking	
Households with driveway area but no garage	0 car		33 households	
	1 car		79 households	
	2 cars		42 households	
	3 or more cars		9 households	
Households with garage	0 car		42 households	
	1 car		101 households	
	2 cars		73 households	
	3 or more cars		24 households	

Notes:
a. GIS data obtained from PATH, NJ Transit, New York City Subway, and MTA Commuter Rail.
b. From 2008 PLUTO files for parcels and New Jersey 2002 Land Cover by Watershed Management Area http://www.nj.gov/dep/gis/lulc02cshp.html#WMA20.

on any public streets. Parking regulations in Santa Monica (CA) allow neither residents nor visitors to park more than two blocks away from their residence.

Different social norms also affect the supply and availability of on-street parking. Although on-street parking is public space following the rule of first come-first serve, many variations exist. For example, residents in low-density neighborhoods often view on-street parking as semipublic or even private space. Parking in front of someone's house without his or her permission may give offense. On-street parking may temporarily become exclusively private. For example, in Chicago, when residents shovel out a spot in front of their own house after a big snowstorm, the spot may become a private space until the snow melts.[3] On-street parking may also remain public, but in reality be semi-exclusive, for example, when an area adopts a resident parking-permit program. In such a case, on-street parking takes on some of the characteristics of off-street parking, but is instead created by regulation.

To solve the data and measurement problems, I rely on aerial photos and street images available from Google Street View and Bing Map to identify household off-street and on-street parking supplies. Compared to traditional surveys, this method is quick, cheap, and has been tested as a reliable approach to auditing pedestrian environments (Clarke, Ailshire, Melendez, Bader, & Morenoff, 2010) and neighborhood physical and social environment (Rundle, Bader, Richards, Neckerman, & Teitler, 2011), capturing the recovery and abandonment of New Orleans neighborhoods after Katrina (Curtis, Duval-Diop, & Novak, 2010), and counting and identifying parking lots in Ohio (Davis, Pijanowski, Robinson, & Engel, 2010) and residential parking in New York City (Weinberger, 2012). The following section describes this method in more detail.

Data Collection: Street Images

The main data sources to identify household on-street and off-street parking supply are Google Street Views, Microsoft Bing StreetSide View, and Bing Birds-Eye View, supplemented by MapQuest aerial photos. I use these multiple sources because they supplement each other and ensure a consistent result. Google Street View provides 360° horizontal and 290° vertical panoramic views at street level based on images taken at approximately 10- or 20-meter intervals from a height of about 2.5 meters. Google launched this service in May 2007 and now covers all large and most medium-sized urban areas in the United States. Bing StreetSide View offers similar street images, but began later, in December 2009, and has a smaller coverage area. Bing Birds-Eye View offers three-dimensional aerial photos from four angles taken at different times, which is very helpful when a garage or driveway is located in the back, at one side of a building, or is blocked by trees from certain perspectives.

The main weakness of this method is in identifying parking for large buildings because their parking facilities may not be visible from either street-side or aerial photos. Researchers also must ensure that the method identifies the correct building. Aerial photos in Google Maps assign a mark to a particular building based on its mailing address, but that mark can be off location in Google Street Views. In some cases, Google and Bing yield inconsistent results and locate different buildings for the same mailing address. In this case, I searched for the same address in MapQuest to ensure the validity of the result. When tax lot maps were available, I identified the problematic household address from the tax lot map and then linked back to Google Maps to locate the exact building. Due to the limitations of this method, I only gathered data on single-family housing and small apartments for this project.

Measuring Off-Street Parking

I measured two types of off-street parking: garages and driveway areas. I measured garages according to the number of spaces they contain, based on the following rules. When a garage door is visible from Google Street Views, I use its width to estimate the number of spaces inside the garage. For example, in Figure 1, the garage door is about 6–7 feet wide, so only one garage space is assigned. When a garage is located in the back of a dwelling and its door is not visible, I use aerial photos from Google Maps, Bing Maps, and MapQuest to identify the size of garage. In most cases, a backyard garage is an independent structure separate from the main building, making this method feasible. For households living in small apartments, when a built-in garage is observed onsite (Figure 2), one space is assigned because tenants normally have access to garage parking even if they decide not to own cars. This garage measurement only counts the possible, not actual, parking spaces inside a garage because residents can utilize a garage for purposes other than car storage.

Driveway area refers to the pavement area on a property usable for car parking. This area includes a parking yard, a driveway in front of a garage, a drive alley, and such. I counted the total number of parking spaces from the street view or aerial photos. The information is often clear for single-family housing. For small apartments, the driveway spaces are divided by the number of units and then rounded up. The final off-street parking supply is the sum of garage and driveway spaces.

Measuring On-Street Parking

I measured the availability of on-street parking as the crowding level of on-street parking around a household's residence. Although straightforward, the measure has two main drawbacks. First, the exact time of day that the aerial photos or streetscape photos were taken is unclear, which is a common problem for image-based data sources (Monkkonen, 2008). Google and Bing refuse to release the timestamps for images because the routing of their photo-taking vehicles is secret (due to both privacy and competitive concerns). Because only the evening crowding level matters to car ownership (Institute of Transportation Engineers [ITE], 2010), this measure is a proxy for the availability of on-street parking. I assume that a crowded street during the day is also more likely to be crowded in evening, so such a proxy will not be a major

Figure 1. Single-family detached housing on Kessel Street in Queens.
Source: Zhan Guo.

(Color figure available online.)

concern. Second, the crowding level indicates how many spaces cars occupy, which itself indicates the car ownership level on that street. If all households park all their cars on the street, the more cars they have and the more crowded the streets are. Such crowding suggests the opposite impact: Less available on-street parking is associated with more car ownership. In other words, this measure tends to underestimate the impact of on-street parking on car ownership.

I measured the crowding level for a 300-foot street segment, with the household's residence being in the middle of the segment. I chose this threshold because there is some evidence that households tend to park cars within 150 feet of their homes (Balcombe & York, 1993). When a street is shorter than 300 feet, I surveyed the entire street segment. I believe this threshold should be sufficient to capture the crowding level of on-street parking around a household.

I measured the number of on-street parking spaces on both sides of the street, after excluding areas at garage and driveway entrances, in front of fire hydrants, in front of no parking signs, and at construction sites. Assuming an on-street parking space occupies a minimum length of 20 feet, the survey area can have a maximum 30 spaces. Depending on the number of parked cars and empty spaces observed out of the approximately 30 spaces available, I ranked the crowding level from 1 to 8 as below:

8 = all parking spaces are occupied by cars;
7 = 1–2 empty spaces out of approximately 30 spaces;

Figure 2. An eight-unit apartment in Williamsburg, Brooklyn.
Source: Zhan Guo.

(Color figure available online.)

6 = 3–4 empty spaces out of approximately 30 spaces;
5 = 5–6 empty spaces out of approximately 30 spaces;
4 = 7–9 empty spaces out of approximately 30 spaces;
3 = more than 5 cars and 9 empty spaces out of approximately 30 spaces;
2 = 3–4 cars and more than 9 empty spaces out of approximately 30 spaces;
1 = 1–2 cars and more than 9 empty spaces out of approximately 30 spaces.

Case Study: New York City Region

The case study area is defined as the immediate outside-core area in the New York City region, including three outer boroughs (Brooklyn, Queens, and the Bronx), 10 municipalities across the Hudson River in New Jersey, and northern Manhattan (north of 110th Street; Figure 3). I excluded the Manhattan core (south of 110th Street) because it has a maximum instead of minimum parking requirement, and the data collection method is less effective for the large buildings located there. Within the study region, I excluded large residential buildings with more than 20 units because it is difficult to identify their parking facilities from street images.

Although its on-street parking is not considered to be in oversupply, the study region, as I discussed above, offers an ideal situation in which to investigate the impact of on-street parking on car ownership. I will discuss the application of the results of the study to lower-density communities at the end of this article. Compared to the metropolitan area, the study region has a higher percentage

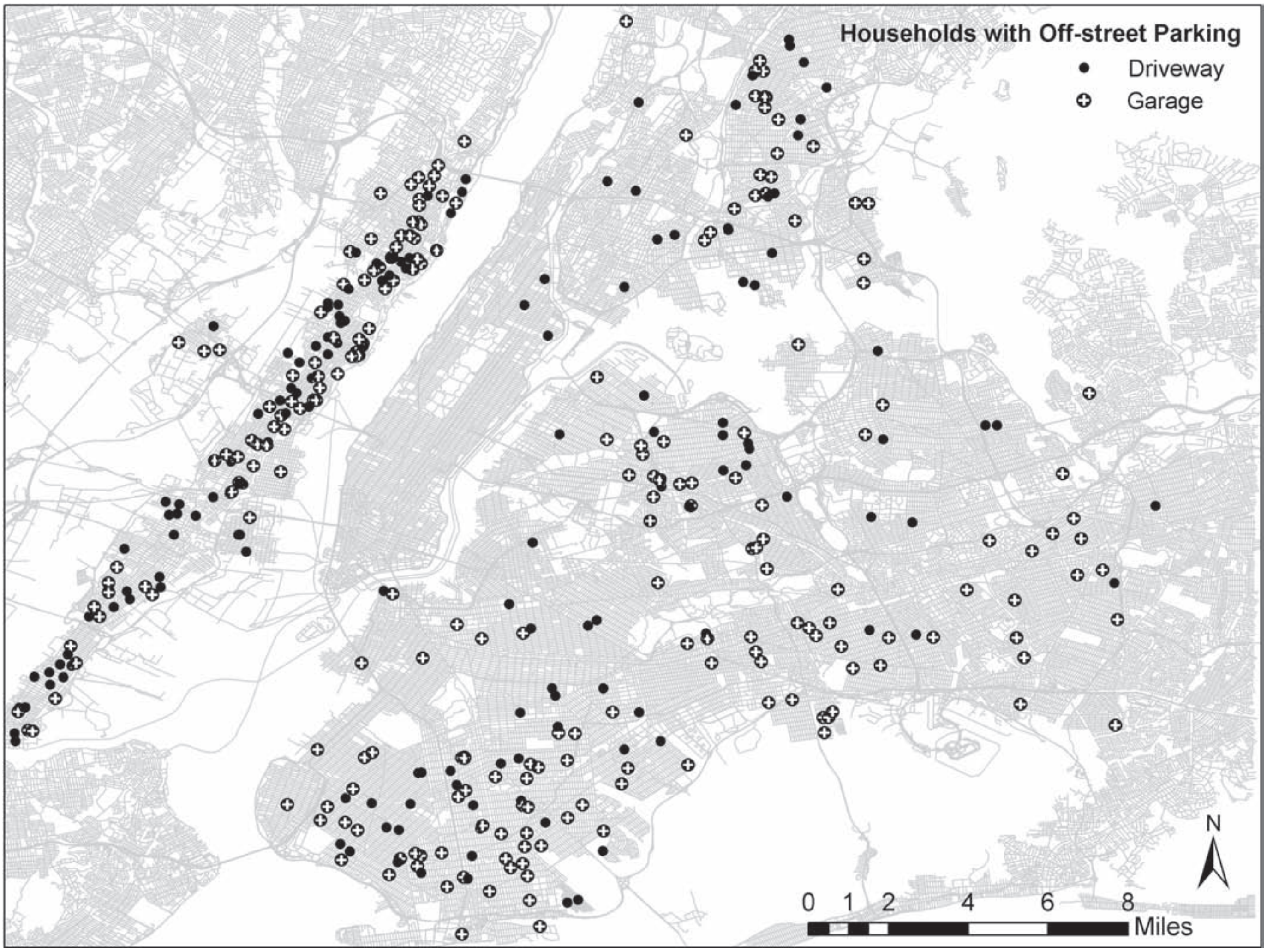

Figure 3. Study region and selected households from the NYMTC survey.

of low-income households (43% vs. 22%), minority occupants (57% vs. 26%), households without cars (34% vs. 20%), and households that occupy apartments and single-family attached housing (61% vs. 44%).

In order to link the parking information to travel-related decisions, I selected households from a regional travel survey. The survey was conducted by the New York Metropolitan Transportation Council (NYMTC) in 1998, the most recent survey of its kind in this region. The NYMTC survey records car ownership and one-day travel activities for a stratified random sample of 11,276 households in the tri-state NJ-NY-CT region on a typical weekday, of which 1,955 households are in the study region. A random sample of 900 households was selected from the 1,955 given the time constraints of the data collection process. Households' home addresses were provided by NYMTC to the author based on a confidentiality agreement. For each household, car ownership information was obtained from the NYMTC survey, while their parking supply was identified through Google, Bing, or MapQuest.

Because the travel and parking surveys were not conducted at the same time, all home addresses were examined through the local building permit databases plus the Certificate of Occupancy database in New York City, which records when a newly completed building is actually occupied by residents. Only those home addresses with no record in either database between 1998 and 2010 are included. These buildings retained the same physical structure between 2010 (the year of the parking survey) and 1998 (the year of the travel survey). I excluded addresses that were unidentifiable and not geocodable through Google Street View. Because I am interested only in households with off-street parking, the final sample size is 407. The average number of off-street parking spaces is 2, with a standard deviation of 1.2.

Figures 1, 2, and 4 show the different types of off-street parking that exist in the study region. Figure 1 is an

Figure 4. Single-family detached housing in Weehawken (NJ).
Source: Zhan Guo.

(Color figure available online.)

example of a typical single-family detached house in the Bronx, with a one-space garage at the back and a long driveway. Figure 4 shows a typical single-family detached house without a garage, but with a parking yard in the front of the house. Figure 2 shows a small apartment building in this region with a built-in garage. Note that many apartment buildings in the study region (57%) do not have any off-street parking.

Regarding the supply of on-street parking, the average crowding level for the 407 households is 5.9 (on a scale of 1–8, with 8 being the most crowded). About 52% of these households live on a street with readily available on-street parking (3–6 empty spaces out of a potential 30).

The Impact of On-Street Parking on Car Ownership

Because the endogeneity between parking supply and car ownership is weak in the sample, I do not correct the endogeneity in the final models. For a detailed analysis of the endogeneity, see the Appendix. I tested several model structures, such as multinomial logit and ordered logit (Ben-Akiva & Lerman, 1985). The on-street variable is statistically significant in both models, with the expected sign. I only report the result from multinomial logit because prior studies indicate this model tends to generate better results than ordered logit (Bhat & Pulugurta, 1998) or nested logit (Salon, 2005). Note Salon's (2005) study used the same survey as I analyze here.

The dependent variable is household car ownership level: zero, one, two, and three or more cars. The control variables include household attributes; such land use characteristics as population and job density, accessibility to transit, and land use mix (Forsyth, 2007); and off-street parking. I include job density within a half-mile buffer from the household's residence for two reasons. First is the conventional argument that if activities are nearby, residents can walk or bike instead of driving, thus reducing the demand for cars. Second, New York City does not have a parking permit program; this allows commuters to park their cars in nearby neighborhoods. This variable might capture the intrusion effect of commuter parking in a neighborhood. Because four households do not have land use information generated within a half-mile buffer, only 403 households were used in the final analysis. I summarize their descriptive statistics in Table 1 and present the final results of the analysis in Table 2.

Most control variables behave as expected. Higher income tends to encourage higher car ownership at all levels. The number of children (17 years old or younger) encourages a household to own two cars, has no effect on

Table 2. Multinomial logit car ownership model.

	Household car ownership level					
	1 Car		2 Cars		3+ Cars	
Independent variables	**beta**	***t***	**beta**	***t***	**beta**	***t***
Constant	–2.09	–1.3	–4.62 **	–2.5	–6.92 **	–2.6
Household attributes						
Household size	0.14	0.5	–0.09	–0.3	0.81	1.6
Income level (1–10 scale)	0.33 **	2.6	0.57 ***	3.7	0.63 **	3.0
# of children (≤17 years old)	0.44	1.2	0.89 *	2.0	–1.24	–1.6
# of workers (full- and part-time)	–0.53	–1.8	0.24	0.7	0.02	0.1
# of driver license	2.36 ***	6.2	3.28 ***	7.4	4.49 **	7.1
Urban form at home origin						
Job density (10,000/square miles)	0.18	0.3	–0.45	–0.6	–3.16 *	–2.1
Pop. density (10,000/square miles)	0.03	0.4	–0.13	–1.1	–0.04	–0.2
Net. distance to subway station (miles)	0.34	1.7	0.41	1.9	0.05	0.2
Entropy within ½ mile of residence	–0.00	–0.0	–0.97	–0.9	–3.34 *	–2.2
In north Manhattan (yes/no, base = NJ)	–13.90	–0.0	–10.80	–0.0	–5.75	–0.0
In Bronx (yes/no, base = NJ)	0.63	0.6	1.25	1.1	–2.51	–1.4
In Queens (yes/no, base = NJ)	0.78	0.9	1.11	1.1	–1.62	–1.1
In Brooklyn (yes/no, base = NJ)	0.67	0.8	0.21	0.2	–3.70 *	–2.2
Parking supply						
Off-street parking supply (# of spaces)	0.40 *	2.3	0.54 **	2.6	0.91 **	2.9
On-street crowding level (1–8 scale)	–0.41 **	–2.8	–0.52 ***	–3.1	–0.48 *	–2.2
Number of observations	N = 403 Households with off-street parking					
Final log-likelihood	–303.05					
Prob. > Chi square	0.0000					
Pseudo R^2	0.3904					

Notes: Land use variables are calculated within the 0.5 mile buffer from the household's residence. Base for comparison: off-street parking with zero cars.
$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

owning one car (probably because it might be a necessity with the presence of children), and tends to deter owning three or more cars (probably because young children reduce the number of eligible drivers in a household). Multiple-worker families tend to have more than one car, but, in general, the number of workers and household size becomes insignificant when the number of driver's licenses is included.

Density (job and population) and mixed-use variables do not matter except for those with three or more cars. This suggests that when parking supply is captured, these land use variables do not exert any additional influence on car ownership, except at the high car ownership levels. Proximity to a train station helps reduce car ownership at the levels of one or two cars (significant at the 10% level), but not for households with three or more cars. Different parts of the study region (New Jersey, Bronx, Queens, Brooklyn, and Manhattan) behave similarly, except for Brooklyn. In Brooklyn, households are less likely to own three or more cars than those in New Jersey. As expected, off-street parking is significant for all car ownership levels. More off-street parking encourages a higher level of car ownership.

Most interestingly, the crowding-level variable is statistically significant, with a negative sign, for all three car ownership levels. This suggests that when streets become less crowded with parked cars, a household is more likely to own one or more cars despite the fact that they have access to off-street parking on their property. The impact on households owning two or more cars is understandable, but the impact on one-car households is a bit unexpected; this finding suggests that even for a household with off-street parking, the availability of on-street parking still matters in their decision to own or not own a car. I think this result indicates two different types of impacts of on-street parking on car ownership decisions: the supply effect and the amenity effect.

The supply effect means that on-street parking increases the total parking supply, so a household is able to buy more cars than their off-street parking would allow. This effect should be more common for households with three or more cars than for households with only one car. In order to test this supply effect, I visually checked through Google Streets the 33 households owning three or more cars (24 with a garage and nine with a driveway). The parking information collected from Google and Bing confirms that at least 14 households (42%, or 10 garage and 4 driveway households) do not have sufficient off-street spaces to hold three or more cars. Many of these households are located at the intersection of two streets and have access to on-street parking on either street.

The amenity effect means that readily available on-street parking in front of one's residence may provide some advantages that off-street parking is unable to offer. These advantages make car usage more convenient. This amenity effect might include, but is not limited to, the ease of parking on streets compared with pulling cars in or out of a narrow garage, especially when the garage is located at the back of the building connected by a narrow drive alley (Figure 1). In order to explore this amenity effect, I investigated where a household parks its cars when drivers have multiple options. Among the 403 households studied, 259 used their cars on the survey day and reported how they parked when they drove home. As Table 3 shows, 95 households (37%) parked on the street instead of in an off-street parking spot. For households with a garage, respondents were actually 2.5 times more likely to park on the street instead of pulling their cars into the garage. The parking habits of drivers from households with only a driveway are equally split between the driveway and on-street parking spaces. To make sure that another car does not occupy their garage or driveway, I further examined the 125 households with only one car, but found the same pattern. This indicates that on-street parking does indeed offer a certain level of utility, otherwise drivers would not choose to park on streets instead of in a garage or driveway. This preference exists despite the fact that streets in the study region are normally narrow and crowded, require parallel parking, and include weekly street-cleaning regulations.

Table 3. Where households park their cars at home.

No. households	**Parking habits (N = 257 households)**			
Parking supply	**In garage**	**On driveway**	**On-street**	**Total**
Garage + driveway + on-street	20	100[a]	45[a]	160
Driveway + on-street	N/A	47	50	97
Total	20	147	95	257

Notes: N/A = not applicable.

a. Five households parked both in the driveway and on the street because they either made multiple vehicle trips and parked at different locations after returning home, or because they had multiple cars.

In order to understand better the impact of on-street parking, I estimated the same model for the two subsamples: households with a garage and households with only driveway areas. For the driveway subsample, the two cars and three or more cars alternatives were combined due to the limited number of observations. The on-street parking effect remains significant for households with a garage, but reduced for households with a driveway; the crowding variable is only significant at the 10% level. This reduction might be due to two reasons. First, the amenity effect of on-street parking is weaker when a household only has a driveway and no garage. Second, because driveway-only households are more likely to park on streets, the on-street crowding measure is also more likely to offset, statistically, the on-street parking impact on car ownership (the weakness of this measure as discussed earlier). The coefficients and t values are summarized in Table 4.

The next question is the size of the impact. Based on the modeling result in Table 3, I simulate the impact of the availability (and unavailability) of on-street parking on the car ownership level in the sample. I increased the on-street parking occupancy level from 1 to 8 incrementally for all 403 households, calculated the predicted car ownership for each step, and compared with the base. The result shows that when on-street parking becomes almost unavailable (crowding level = 8), the average car ownership would be reduced by 8.8% from the current level (1.27–1.16 cars per household). In other words, 1 out of 11 (1/0.088 = 11.3) cars owned by these households could be explained by the present availability of on-street parking. That is equivalent to 165,455 cars in the study region.[4] Assuming the annual average miles per vehicle in this region is 6,480 (Weinberger et al., 2009), this translates into 1.6 miles per day per car. If on-street parking is abundant and always available (crowding level = 1), car ownership will increase by almost 18% (1.27–1.50 cars per household), equivalent to 327,600 additional cars in the study region. These results indicate that free and available on-street parking could significantly affect household car ownership, even when off-street parking exists.

Discussion and Policy Implications

These findings might not surprise New Yorkers or residents of other old urban communities. On-street parking is important to them due to the general shortage of off-street parking. However, can we generalize these findings to other metropolitan areas, especially those with medium- or low-density and sufficient off-street parking? Before answering this question, consider the following news report (Figueroa, 2010).

Mark Shoff is a 51-year-old resident in Covina, a low-density town 20 miles west of downtown Los Angeles. His house has a two-space garage and a spacious driveway that could park up to five cars, together allowing Mr. Shoff to park a maximum of seven cars on his own property. His house is at the corner of two streets, so he also has direct access to about nine on-street parking spots. Mr. Shoff could own and park 16 cars without bothering his neighbors if he takes advantage of these extra on-street spaces. Indeed, he did. However, the total was not seven, nor 16, but 48 cars, which he parks on streets throughout the neighborhood. Neighbors complain but can do nothing because it is legal. While Mr. Shoff might be an extreme case, there is no reason to believe that residents with sufficient off-street parking in low-density communities would not exploit the free on-street parking spaces in front of their houses.

The results shed light on the behavioral consequences of several residential parking policies. Regulations over the usage of existing street parking in residential neighborhoods are likely to affect car ownership and usage. These regulations include but are not limited to time restrictions, such as no overnight parking or 72-hours maximum, and usage exclusion, such as resident parking permits. However, these regulations are either ineffective due to the difficulty in enforcement or only implemented in a small number of areas. A more fundamental question is: Why do local governments require dedicated parking lanes in street width standards, especially when off-street parking is already mandated (and often oversupplied)?

Unfortunately, a clear answer is difficult to come by. Street standards began to mandate street parking in the 1930s, such as those developed by the Federal Housing

Table 4. Coefficient and *t* statistics of on-street crowding for two subsamples.

Subsamples	1 Car	2 Cars	3 Or more cars
Households with off-street parking ($N = 403$)	–0.41 (–2.8)	–0.52 (–3.1)	–0.48 (–2.2)
Households with garage ($N = 239$)	–0.57 (–2.5)	–0.70 (–2.8)	–0.80 (–2.7)
Households with only driveway ($N = 164$)	–0.52 (–1.8)	–0.60 (–1.9)	

Administration (FHA, 1936). The minimum pavement width was set to 24 feet, sufficient for one parking lane. The width increased to 32 and 34 feet in the 1960s, such as the "Recommended Practice for Subdivision Streets" published by the ITE (1967), which essentially mandated parking on both sides of residential streets. However, in all documents, the rationale of mandating street parking is not well documented and explained. The policy seems to exist more in the illustration of section design than in texts.

The author interviewed public works officials from 15 cities, inquiring about their reasons for providing on-street parking when off-street parking is already required.[5] Respondents mentioned visitors and service vehicles seven times and extra spaces for residents four times, but six cities did not answer this question in their responses. At first glance, there appears to be little consensus on exactly why on-street parking is provided.

One possibility is that on-street parking is requested by developers or residents. Actually, developers have opposed the minimum street standard since its inception. For example, the Urban Land Institute (ULI), sponsored by the National Association of Real Estate, has advocated lower street standards to cut construction costs and to lessen the burden on developers. ULI's (1947) recommendation has included maximum, instead of minimum, street widths since 1947. In a survey for residential developers by Ben-Joseph (2003), street width requirement was voted as the single most excessive government regulation during the development process (75%). Without governmental minimum street standards, developers are unlikely to provide on-street parking at the current level.

For example, narrow streets without on-street parking is the case in many private communities where homeowner associations own and maintain the streets. In Baldwin Park, a private subdivision in Orlando (FL), streets are only 20–22 feet wide without dedicated parking lanes. Designated parking areas are provided along major roads surrounding the subdivision (C. Bolena, personal communication, October 13, 2010). Village Home, a subdivision in Davis (CA), eliminated on-street parking completely in their street design. The space saved can be used for wider sidewalks, new bike lanes, expanded open space, or new playgrounds. Only 13% of developed land is devoted to streets compared to the typical 40%–50%. Open space and parks account for 40% of the land area, and a natural drainage system, with creek beds, swales, and ponds is sufficient to absorb storm water due to the small impervious area in the subdivision (Village Home, 2009).

Although they may not articulate reasons for doing so, local governments might be aware that they force developers to create excessive on-street parking. According to a survey of 75 cities in 1995 (Ben-Joseph, 1995), about 84% of local governments allow for different street standards in private developments. In Las Vegas, for example, the local government offers developers two options: They can build public streets or private streets in the development. In the former case, streets must be at least 33 feet wide, while in the latter case, 24 feet is sufficient (R. Fultz, personal communication, December 7, 2010). It is unclear why public streets need on-street parking, but private streets do not.[6]

Many residents would be unlikely to pay for on-street parking if they knew its true cost. Some residents may view on-street parking as a free service, akin to welfare, provided by the government. However, no public space is free. When a developer directly provides on-street parking, the cost is included in the housing prices. When a local government provides such parking, property taxes pay the (construction) costs. In either case, residents eventually bear the burden. According to Litman (2007), one on-street parking space in a suburban setting costs $3,800 to construct and $300 annually to maintain. Therefore, an average single-family household with four on-street parking spaces would pay $15,200 ($3800 × 4) for capital costs and $1,200 ($300 × 4) annually for operational costs for those spaces. Note the national median annual property tax is only $1,850, and residents do not have ownership of on-street parking, it remains as public space, which everyone can use.

Therefore, the on-street parking mandate in minimum street standards is likely to force the market to create excessive on-street parking and distorts residents' consumption by bundling the true cost of on-street parking with housing prices. The problems resemble those that arise from the minimum off-street parking requirement. As shown by this research, without free, oversupplied, on-street parking, households in general are likely to buy fewer cars and drive fewer vehicle miles. Without the minimum on-street parking requirement, residential developments are likely to be more compact and housing more affordable. The policy recommendation thus is to abolish the minimum on-street parking requirement for new residential developments (or when retrofitting existing streets) and let the market decide whether and how on-street parking should be provided to residents. Because the U.S. population will grow by another 100 million by 2060 (U.S. Census Bureau, 2012), and between 70% and 90% of this growth will occur in greenfield developments (Heid, 2004), this policy change could potentially affect the fate of millions of cars and have a tremendous impact on our built environment and sustainable future.

Conclusion

This research investigates an important, but often overlooked, parking problem: the minimum on-street parking requirement that is linked to the minimum street-width standards. This requirement oversupplies the free on-street parking that is prevalent in many communities in the United States. Based on 403 households randomly selected from the New York City region, this research demonstrates that free and available on-street parking encourages private car ownership, despite the fact that these households already have off-street parking. One out of 11 cars in the study region can be explained by the availability of on-street parking. This indicates the significant behavioral consequences of providing free and abundant on-street parking in residential neighborhoods.

The followup policy discussion shows that it is unclear, to both decision makers and scholars, why on-street parking is required and what the benefits are of such parking, especially given the tremendous resources spent on it. Developers have fought to lower this minimum requirement and residents are unlikely to write the check if they know the true costs of on-street parking. Local governments seem to be aware of the need for change, but have been unresponsive. The policy recommendation is to abolish the minimum on-street parking requirement and let the market decide whether and how to provide it in residential developments. Without addressing this on-street parking problem, discussion of an efficient, effective, and equitable parking policy would be incomplete.

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Notes

1. Garages are very standardized in size and have not changed over time. Based on Residential Energy Consumption Surveys conducted by the Energy Information Administration, it is known that a one-car garage averages 250 square feet in size, a two-car garage is 400 square feet, and a three-car garage is 600 square feet in size. The average garage size is 525 square feet, or 2.6 spaces (http://www.eia.doe.gov/emeu/recs/sqft-measure.html).

2. According to the U.S Census Bureau (2011), the average lot size in metropolitan areas is 15,706 square feet (0.36 acre). This is the average value for new homes sold from 1976 to 2008, assuming an average frontage and depth ratio of 2:3, and that the average length of an on-street parking space is 20 feet. Curb cuts could be either included or excluded (http://www.census.gov/const/C25Ann/medavgsoldlotsize_cust.xls)

3. Such a rule is commonly accepted in Chicago as described by Mayor Daley's words: "I tell people, if someone spends all that time digging their car out, do not drive in that spot. This is Chicago. Fair warning." Violators could be warned by stickers placed over the windshields, or punished by flat tires, dents on the fenders and doors, smashed side mirrors and windows, or even force (Epstein, 2002, p. S529).

4. Assuming the study region has 6.9 million people (6.3 million from the three New York City boroughs and 0.6 million from the New Jersey cities), there are 2.76 million households (average household size 2.5), among which 52% (403/770, 1.44 million) has off-street parking. They own $1.44 \times 1.27 = 1.82$ million cars.

5. The 15 cities are: Birmingham (AL), Phoenix (AZ), Tucson (AZ), Mesa (AZ), Berkeley (CA), Los Angeles (CA), San Jose (CA), Washington (DC), Atlanta (GA), Greensboro (NC), Las Vegas (NV), Cleveland (OH), Cincinnati (OH), Minneapolis (MN), and Houston (TX). The exact question asked was: "For the single-family housing neighborhoods developed over the past 20 years in your city, do you still provide on-street parking even when households have sufficient or even oversupplied off-street parking due to the minimum parking requirement? If Yes, could you explain why since residents already have enough parking on their own property (garage + driveway)?"

6. One explanation is liability. Cities are concerned with liability when they deviate from street standards in the ITE handbook, but such a concern does not exist for private developments. However, homeowner associations are more vulnerable than local governments when faced with liability litigations. If the liability concern is real, private streets should be wider instead of narrower than public streets.

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Appendix: Tests of the Endogeneity Between Parking Supply and Car Ownership

I follow a similar approach used by Boarnet and Sarmiento (1998) to test the endogeneity between parking supply and car ownership. Five instrumental variables (IV) were developed:

1) single-family detached housing (yes/no, base = apartment),
2) single-family attached housing (yes/no, base = apartment),
3) average age of building stock in the census block group,
4) the percentage of Black population in the census block group,
5) the percentage of Hispanic population in the census block group.

The following endogenous variables are tested:

1) off-street parking supply (single endogenous variable),
2) on-street parking crowding (single endogenous variable),
3) off-street parking and on-street parking availability (two endogenous variables).

Variable 1 assumes that only off-street parking is factored into residential location decisions; variable 2 assumes they only on-street parking is taken into account; while variable 3 assumes that both on-street and off-street parking are factored into the residential location decision.

The Sargan over-identification test was first conducted to check whether the selected instrumental variables are valid. Then, the Hausman endogeneity test tests whether the endogeneity actually exists (Larcker & Rusticus, 2005). The higher the p value for the Sargan test, the more likely the instrumental variables are valid. The higher the p value for the Hausman test, the more likely that endogeneity does not exist. Results (Tables A-1 and A-2) suggest the selected instrumental variables are valid in all three models, but the endogeneity appears to be either weak or not exist probably due to the relatively homogenous sample used for this research.

Table A-1. Instrumental variable models.

			Two-stage least square (2SLS) Endogenous variables =					
	Ordinary least square (OLS)		No. of off-street parking		On-street parking crowding		Off-Street and on-Street	
Independent variables	**beta**	***t***	**beta**	***t***	**beta**	***t***	**beta**	***t***
Parking supply								
Off-street parking supply	0.07	2.5			0.07	2.2		
On-street crowding (1–8 scale)	–0.06	–2.9	–0.05	–2.1				
Predicted off-street parking supply			0.25	2.2			0.24	1.9
Predicted on-street crowding (1–8 scale)					–0.13	–1.7	–0.08	–0.8
Number of observations	$N = 403$		$N = 403$		$N = 403$		$N = 403$	
R^2	0.4982		0.4533		0.4958		0.4585	
Sargan overidentification test (prob.)			0.1918 ($df = 4$)		0.0808 ($df = 4$)		0.1085 ($df = 3$)	
Hausman endogeneity test (prob.)			0.1029		0.3775		0.2522	

Notes: Dependent variable = number of cars in a household.

Table A-2. First stage OLS regression models.

	Dependent variable=							
	On-street crowding		Off-street		On-street crowding		Off-street	
Independent variables	**beta**	*t*	**beta**	*t*	**beta**	*t*	**beta**	*t*
Instrumental Variables								
Single-family detached	–0.50	–2.4	0.66	4.6	–0.46	–2.1	0.66	4.6
Single-family attached	–0.27	–1.1	0.78	4.7	–0.22	–0.9	0.78	4.7
Average year of built	0.03	3.4	0.01	0.9	0.03	3.4	0.00	0.9
Percent of Black population	–0.17	–0.7	–0.15	–0.9	–0.18	–0.7	–0.15	–0.9
Percent of Hispanic population	0.61	2.6	–0.29	–1.8	0.59	2.5	–0.29	–1.8
Exogenous Parking								
On-street crowding							–0.03	–0.8
Off-street supply					–0.06	–0.8		
Number of observations	$N = 403$		$N = 403$		$N = 403$		$N = 403$	
R^2	0.2542		0.1490		0.2555		0.1893	

Notes: In both tables, other independent variables estimated but not presented here include: constant, income, number of children, number of workers, number of driver licenses, job and population density, network distance to subway station, land use mixture, and four Borough dummy variables.