Teardowns, Popups and Bump-Outs:
How does housing supply change?

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Abstract

Cities grow in layers over time. As population and land values increase, older, smaller buildings are replaced with higher density, higher value structures. However, direct costs of redevelopment, and political and institutional barriers such as zoning, may constrain replacement of older structures, leading to alternate forms of redevelopment. In this paper, I use administrative data on building permits in Washington DC to examine variation in the type and location of residential investment. Results suggest that residential investment occurs in several different forms. The type and quantity of investment varies across neighborhoods. Additions and alterations are more common in neighborhoods with high housing values and older housing, but the location of new construction is more idiosyncratic.

Keywords: Housing supply; land values; zoning; urban spatial structure; construction; local government

JEL codes: H7; L74; O18; R1; R3; R5

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1) Introduction

Cities grow in layers over time. As population and land values increase, older, smaller buildings are gradually replaced with higher density, higher value structures. Many city centers show vestiges of their previous iterations: small townhouses wedged between towering skyscrapers, historic churches nestled within modern financial districts. This pattern of redevelopment is consistent with the standard urban model, which predicts that real estate density should increase with rising land values (Alonso 1964; Mills 1967; Muth 1969). Whether and when redevelopment occurs depends on the total costs of redevelopment and the difference between expected rents from the current structure and from potential new structures (Clapp et al 2012; Munneke and Womack 2015; Wheaton 1978). Cities and neighborhoods that have experienced large increases in underlying land values since the previous development wave, or where current structures are in poorer quality or functionally obsolete, should face stronger incentives for redevelopment. However, both market-based factors and political and institutional barriers may inhibit replacement of older structures. Direct costs of demolition and construction are higher in densely built urban areas than in unbuilt "greenfields". Older neighborhoods often are divided into many small parcels, requiring costly and difficult land assembly, to facilitate building substantially larger structures (Brooks and Lutz 2016, Cunningham 2013). And institutional barriers such as zoning or political opposition may constrain redevelopment, particularly for high density buildings (Glaeser et al 2005, Hilber and Vermeulen 2016, Quigley and Rafael 2004, Schuetz 2009, Schuetz et al 2017). If the transaction costs of demolition and replacement are sufficiently high, or if land use regulation is a binding constraint on the density of new buildings, housing investment may take different forms than complete redevelopment. In this paper, I use administrative data on building permits in Washington DC to explore how economic and institutional factors affect the quantity and form of housing investment.

Theoretical discussions of redevelopment largely focus on two types of changes that will result from increased land values: a conversion from low-value to higher-value land uses (i.e. from industrial to commercial or residential) and an increase in the intensity of development (greater capital to land ratio). Most commonly, these involve demolition and rebuilding, potentially also with assembly of a larger land parcel, but can also be accomplished through less costly and more visually subtle changes to existing structures. Academic research and general media accounts provide evidence on various ways that property investments are taking place in high-value cities with relatively old building stock. Ahlfeldt and McMillen (2015) find that, over more than 100 years, downtown Chicago has seen substantial redevelopment into ever taller skyscrapers, due to rising land values. Focusing particularly on Chicago's residential market, Dye and McMillen (2007) find that small, older single-family houses near location-specific amenities are often targeted for "teardowns", in which existing houses are demolished and replaced by larger homes on the same parcel. In recent years, London's notoriously restrictive housing market has experienced growth in high-end basement excavations, which create underground living spaces that may exceed the above-ground square footage, known as "iceberg houses" (Dowling 2014, Financial Times 2014, Smith 2016).

In Washington DC, many residential neighborhoods are dominated by two- and three-story 19th century rowhouses that are considerably smaller than most newly built houses. To expand the interior space in these houses, homeowners and developers are employing several different mechanisms. "Popups" add stories on top of the older buildings, while "bump-outs" or "pop-backs" extend the building footprint to the side or back of the existing structure (Alpert

2015, Shapira 2015). Often these expansions are accompanied by general interior and exterior renovations, or changes in the number of units per structure (i.e. converting a single-family house into multiple apartments, or vice versa). Figure 1 shows examples of some building alterations in the Columbia Heights neighborhood. The top left panel shows a relatively modest pop-up, not accompanied by other exterior renovations. The top right and bottom left panels show more noticeable and extensive popups, which substantially increased the size and altered the external appearance of the structures; both of these renovations included conversion from single-family status to multiple unit condominiums and extensive interior renovations. The bottom right photo shows an end rowhouse that was bumped out to the left side, creating roughly 50 percent more frontage, along with an extra story on top of the addition.

Recent housing market conditions in Washington DC offer a useful empirical setting to test theories of redevelopment. After population decline and disinvestment during much of the 20th century, the city has experienced substantial gentrification since the late 1990s, with widespread increases in housing values and greater demand by higher-income (and mostly white) households for traditionally low-value, mostly African-American neighborhoods. The increase in total population and household income in many previously low-value neighborhoods creates a potential mismatch between the existing housing stock and preferred dwelling size and quality for new residents. Moreover, DC has a number of idiosyncratic restrictions on building supply, including a strict height limit (relative to street width), historic preservation rules that apply to many of the highest-value neighborhoods, absolute constraints on jurisdiction land area (the District is surrounded by two neighboring states, barring municipal annexation), and the presence of a large institutional landowner (the federal government). These supply constraints may increase the necessity for creative reuse of developable land and existing structures.

The analysis examines administrative data from the District of Columbia city government to establish several stylized facts about residential investment. First, I describe the forms of residential construction activity that took place from 2008-2016, distinguishing between new construction of residential units, expansions of existing structures, and other renovations. Second, I describe spatial patterns of the quantity and type of housing investment across neighborhoods in DC. Third, I conduct preliminary analysis of how baseline neighborhood characteristics are correlated with the quantity and type of housing investment, focusing particularly on determinants of housing (land) values.

Results suggest housing investment can take many different forms, and that the type and quantity of investments vary substantially across neighborhoods within the city. New construction is a relatively small share of housing investment, compared with additions and renovations to existing structures. New construction is also much more spatially concentrated than additions and alterations. Spatial patterns of housing additions and alterations can be explained fairly well by proxies the standard urban redevelopment model: they are more prevalent in neighborhoods with higher pre-existing housing values, older and lower density housing. By contrast, spatial patterns of new construction are more idiosyncratic.

The remainder of this paper is organized as follows. Section 2 describes the data and empirical approach. Section 3 presents results from descriptive analysis. Section 4 outlines directions for additional research and concludes.

2) Data and empirical approach

The analysis makes use of several administrative datasets from local government agencies within the District of Columbia, as well as tract-level ACS data on demographic and housing characteristics. The empirical approach at this stage uses mostly descriptive statistics and some preliminary regression analysis to explore the relative importance of market conditions and political or institutional factors in residential investment patterns.

2.1) Data sources

The primary dataset is an inventory of building permits issued by the District of Columbia's Department of Consumer and Regulatory Affairs (DCRA) between September 2008 and June 2016. Building permits are reviewed and approved by DCRA, and records of permits are publicly available on opendata.dc.gov. Pertinent variables include the location of the property (street address and latitude-longitude coordinates), the permit application date, and several variables describing the type of work undertaken. DCRA assigns each building permit a primary and secondary category, based on the type of work. This analysis focuses on several secondary groups within the primary "Construction" category: new building, addition, and alteration and repair.[1] As shown in Table 1, about 86 percent of construction permits fall into these categories.[2] The exact nature of work conducted under secondary categories is quite diverse, particularly for the Addition and Alteration permits. Table 4 shows the open-ended "description of work" included in the permit data for all three categories. Both new building and addition categories includes projects that involve the creation of additional residential units within an existing structure (for instance, reconfiguring a single-family house into two or more units). Therefore the total number of housing units permitted under DCRA's "New Building"

[1] The four primary categories other than Construction are Home Occupation (license for certain commercial activities within a residential building), Postcard (a simplified application for minor repairs that homeowners can describe "on a postcard"), Shop drawing (architectural plans), and Supplemental (includes boiler, mechanical, elevator, and plumbing licenses).

[2] This analysis groups the small sub-categories "Addition" and "Addition, Alteration and Repair" together, while leaving the "Alteration and Repair" and "New Building " sub-groups separate. Most of the other sub-categories within Construction do not involve modifications of residential structures.

category does not match total units permitted in the Census Bureau's "New residential construction" series.

To capture the specific types of investment activities, I use machine learning to classify the open-ended "description of work" field. First, I review and manually code approximately 1300 observations from the dataset. This sample was stratified by the three building permit types, because the types of activity vary across permit categories. The new variables created are shown in Table 5. At least 50 examples are needed for each investment activity, to provide a sufficient sample for the machine learning. Some activities are relatively rare or geographically quite concentrated, including popups and single-family to two-family conversions. Therefore I oversample selected ANCs with high prevalence of these activities in order to reach the 50 case minimum. The sample of manually coded observations is then used to "teach" the computer to classify the remaining 33,000 observations, based on the text patterns observed in the "description of work" field. In order to check the accuracy of the classification, I cross-validate the data: each iteration of coding withholds 10% of the non-coded observations, to test out-of-sample predictions. The process of coding 90% and testing the remainder is repeated multiple times, in order to compare classification of the same observation across repeated iterations. The classification and cross validation is currently underway; results are not yet available.

To obtain current (post-renovation) property characteristics, I merged the permit dataset with several other DC administrative datasets. Land use categories are drawn from the property tax assessment dataset. Counts of housing units per structure and other physical building characteristics are drawn from supplemental datasets used by the Office of Tax Records for assessing property values. Because the focus of the analysis is residential investment, construction permits affecting purely commercial properties were excluded, although mixed-use residential-commercial buildings are included.[3] This analysis includes the following property types: detached and attached single-family structures, apartment buildings, condominiums, cooperatives, and mixed-use residential-commercial properties. A planning dataset identifies the census tract and local government district of each parcel. DC is divided into eight Wards of roughly equal population for federal voting purposes; these Wards also determine city council representation and have strong historical and social identities. Each Ward is subdivided into smaller Area Neighborhood Councils (ANCs), each represented by a volunteer Commissioner. The ANCs have some input into neighborhoods zoning, land use and development decisions.

Besides the DC administrative datasets, the analysis uses tract-level population and housing characteristics from the 2006-2010 ACS. Locations of Metro (subway) stations were obtained from the Washington Metropolitan Area Transit Authority (WMATA) website. Variable definitions and sources are shown in Table 2; summary statistics for all variables are shown in Table 3.

2.2) Empirical approach

The conceptual framework for the analysis is a simplified version of the urban redevelopment model posited by Wheaton (1978), which implies that existing structures should be redeveloped if the redevelopment will increase the expected net present value of the parcel, after accounting for development costs. This relationship is illustrated in Equation 1 below.

(Eq. 1) $$\sum_{t=1}^{n} \frac{Rent*SqFt}{(1+r)^t} < \sum_{t=1}^{n} \frac{Rent'*SqFt'}{(1+r)^t} - Cost$$

[3] Each land/tax parcel is assigned a unique ID, the square-suffix-lot (SSL) number, which allows merging administrative datasets. For new construction properties in which the SSL changed between the prior and new building, street addresses were used to identify the current SSL.

In this model, the landowner currently receives a given rent per square foot, Rent, which is determined by the existing structure's age and quality. The owner/developer can choose to leave the structure as is, or make modifications to it that would have different expected redevelopment costs, and would yield varying future rents (Rent') and alternate building square footage (SqFt').

Traditionally, this model has been used to predict the demolition and replacement of low-density, low-value structures with higher-density and newer structures. However, if there are binding constraints on building height or floor-to-area ratio, or if complete replacement is extremely costly, owners/developers may choose to make less drastic improvements. Pop-ups and bumpouts could increase rentable square footage, while interior renovations such as kitchen and bathroom upgrades could increase rent per square foot, with much smaller redevelopment costs.[4] Thus, considering the full range of redevelopment options may yield different predictions for which parcels receive housing investments. As discussed in the introduction, residential investments run the gamut from large-scale redevelopment with land assembly of multiple parcels, teardowns and replacement on existing parcels, expansion of the existing structures without replacement, interior reconfiguration to change the number of residential units, as well as interior and exterior renovations. What type of renovation happens where will depend on the size of the mismatch between current net present value and expected future net present value, as well as the developer's ability to implement the desired investments.

The analysis in this paper seeks to answer three questions, two of which are primarily descriptive. First, what types of residential investment occurred in Washington DC during the 2008-2016 time period? What are the frequencies of less studied investments, relative to new construction? Second, what is the correlation between the quantity and type of housing

[4] Other papers have discussed the option value of future redevelopment; owners may choose not to implement minor investments in properties today if they anticipate larger gains from full redevelopment at some point in the future.

investments and initial neighborhood economic, political, and institutional characteristics? Third, do zoning and local political pressures distort the location and type of housing investments?

Underlying the third research question are two implicit hypotheses. Is redevelopment driven by a mismatch between current and future NPV (i.e. high land values in areas with low density and/or poor quality housing)? Do zoning or neighborhood opposition that limit redevelopment in areas where there are NPV mismatches? In areas where zoning and politics constrain higher density redevelopment, does housing investment get channeled into lower-visibility forms? The current analysis addresses the first two questions, but cannot yet identify for causal relationships between redevelopment, land values, and institutional constraints. Results presented here are descriptive and can only be interpreted as correlations.

To explore these relationships, regressions of the following form are estimated:

(Eq. 2) $Permits_i = \beta_0 + \beta_1 Value_i + \beta_2 Structure_i + \beta_3 Location_i + \beta_4 Demographics_i + Nhood_j + \varepsilon_i$

where i indexes the census tract and j indexes the larger neighborhood (ANC). Although the permit data spans nearly eight years, the regressions pool all permits over the time period, both because annual permit data is highly noisy and because the number of permits per tract-year is very small for most tracts. As dependent variables, I use the number of permits in each of three categories of interest: additions, alterations and new building. Census tracts vary somewhat in size of housing stock, so permit counts are divided by initial housing unit counts (ACS).[5] As a proxy for underlying land values, I use the values of owner-occupied housing from the ACS. The two key structural characteristics that should influence redevelopment are housing density

[5] The housing unit counts are taken from the five-year ACS, 2006-2010. This overlaps slightly with the permit time period, 2008-2016, but in practice, almost no new housing was built during the overlapping years, due to the lingering effects of the Great Recession and housing crisis.

and quality; these are proxied by housing units per acre and share of housing built before 1940. As further proxies for land values, I include two locational characteristics: distance from the central business district (CBD), as defined by the DC City Hall, and distance from the nearest Metro station. Demographic characteristics include median household income, share of college-educated residents, share of owner-occupants, and black and Hispanic population shares. Fixed effects for ANC are included to control for unobservable neighborhood characteristics, including local residents' preferences about land use and development.

2.3) Identification challenges

Of course, there are substantial challenges to identifying a causal relationship between housing investment and regulatory or political constraints. One key concern is potential selection bias in the permit data. I only observe permits that were granted, which misses (a) permit applications that were denied, (b) latent work that owners would have liked to do, but didn't even apply for permits because they anticipated the request would be denied, and (c) activity that was carried out illegally without obtaining a permit. Quite likely, these unobserved outcomes are correlated with neighborhood characteristics. It seems plausible that permit applications are denied (or not applied for in the first place) in neighborhoods with restrictive zoning and/or highly engaged neighbors who will fight the proposed investment. From prior research, these are probably neighborhoods with high levels of human, financial and social capital. On the other hand, locations where investment activity is undertaken illegally without obtaining a permit may be neighborhoods where neighbors are relatively disengaged or disenfranchised, and thus unlikely to report it to the local government. Additionally, work carried out without permits may be smaller scale or less visible to neighbors (interior renovations requiring little outside labor) or work done by the homeowner, rather than licensed contractors.

Contractors that frequently do with in DC will presumably be hesitant to flagrantly violate city laws, in fear that they will no longer be allowed to do business, whereas most homeowners may regard their own renovations as a one-time event.

There are several other types of data that could be useful for more precise identification of political or institutional constraints. Information on zoning classifications, historic preservation, planned redevelopment areas, and other land use regulation at the beginning of the period would allow for direct testing of these features. Some of this information is available for current parcels, but it is unclear how much zoning has changed since 2008. If it is possible to obtain a pre-2008 parcel file of land uses and structure characteristics, it would be possible to conduct a parcel-level transition analysis, that could account for different outcomes of similar parcels located in different ANCs, or make use of time-varying ANC-specific policies. Information such as partisan affiliation or voting patterns by neighborhood could also be obtained to infer strength of political engagement or local policy preferences; DC residents are overwhelmingly affiliated with the Democratic party, but races for local government races such as mayor and City Council often feature debates over proposed developments.

3) Results

Several stylized facts emerge from the analysis. First, residential investment takes many different forms, of which new construction is a relatively small share. Second, the quantity and type of investment varies substantially across DC neighborhoods. Third, some of the spatial patterns of investment fit well with the "NPV mismatch" hypothesis, but the location of new construction appears to be more idiosyncratic.

3.1 What forms does residential investment take?

Between 2008 and 2016, DCRA issued nearly 41,000 permits for residential construction projects (Table 1). The vast majority of permits were for alterations of existing structures (72%), the least extensive of the three permit categories studied. Permits for new buildings represented only four percent of total permits, although the number of new units permitted is nearly 10 times the number of structures.[6] The reason for this discrepancy is that most new housing units built during this period were in large multifamily structures (Figure 2). More than 90 percent of new building permits were for one-to-four family buildings, but over 70 percent of new units are in buildings with 51 or more units.

The type of investment activity varies by structure type and size (Figure 3). Most addition permits were issued for changes to single-family detached houses or townhouses (about 40 percent each). Alteration permits were mostly issued for townhouses, with smaller shares for single-family detached and low-rise apartment buildings. Addition and alteration permits were infrequently used for high-rise apartment buildings or condo/coop buildings of any size. By contrast, newly built units were mostly in high-rise apartment or condo/coop buildings. Some of these differences may reflect vintages of buildings by type and size: many of the single-family houses and townhouses in DC were built prior to 1940, while most of the condo/coop and large apartment buildings were built after 1980.

3.2 Does the type and quantity of residential investment vary across neighborhoods?

Spatial variations in the type and quantity of building permits are clearly visible, measured at several different geographic levels. Figures 4-6 show tract-level densities of permits for additions, alterations, and new housing units. To provide more context for the spatial

[6] Throughout this analysis, I generally present the quantity of new building by unit counts, because of the prevalence of large multi-unit structures. Addition and alteration permits are shown as permit counts, because it is usually not possible to determine how many units within a building might be affected by additions or alterations (i.e. whether an alteration to a multifamily building affects a single unit, multiple units or building common space).

patterns, boundaries for DC's eight Wards are also shown, as are the location of Metro stations. Census tracts with the highest concentration of addition permits are located in the city's northwest quadrant, in Wards 3 and 4, as well as parts of Ward 6 east of downtown. Ward 3 and the far northwest part of Ward 4, along the Maryland border, are some of the most affluent neighborhoods, while Ward 6 includes the historic Capitol Hill neighborhood. Census tracts with the lowest concentration of addition permits include those surrounding the CBD and the National Mall, and most of Wards 7 and 8. Residential buildings near the CBD are largely high-rise apartment buildings of relatively recent vintage. Wards 7 and 8 are located southeast of the Anacostia River, and are historically among the poorest parts of the city. The correlation between neighborhood characteristics and investment will be more formally tested in Section 3.3, but the map is suggestive that permits for additions are more prevalent in high-value residential neighborhoods.

The spatial patterns among alteration permits are similar, although somewhat less clear visually (Figure 5). Tracts with high concentrations of alterations are clustered in the Georgetown neighborhood of Ward 2, the Capitol Hill district in Ward 6, and along a north-south corridor in Wards 1 and 5 (roughly corresponding to North Capitol Street, which divides the Northeast and Northwest quadrants). Georgetown and Capitol Hill are affluent and established neighborhoods, while the North Capitol corridor has experienced rapid gentrification during the past 10 years. Similar to Figure 4, Wards 7 and 8 generally have lower concentrations of alteration permits, although these is variation across tracts within these wards.

New residential construction is less prevalent than addition and alteration activity throughout the city, and much more spatially concentrated (Figure 6). Tracts with the highest tier of concentration (more than 100 new units per 1000 existing units) are found in Wards 1, 3, 5 and 6, but not spread uniformly throughout those Wards. Some tracts with concentrated new building are located immediately adjacent to Metro stations, particularly along the Yellow/Green lines in central Northwest DC and several Red Line stations, but other tracts near Metro stations have little or no new building. Some tracts on the far eastern boundary of Wards 5 and 7, adjacent to Prince George's County, Maryland, have relatively high new building concentrations.

One limitation of using a simple count of permits (or new units) as a measure of investment is that the permit categories cover a wide range of activities, which will vary in construction costs and expected increases to rent and/or structure square footage. Moreover, the types of additions and renovations are likely to vary by initial structure characteristics; for instance, houses on small lots are less able to expand the building footprint, and high-rise buildings are unlikely to add stories on top. Future analysis of spatial patterns for more narrowly defined investments will allow me to test whether neighborhoods with similar initial housing stock (for instance, older rowhouse neighborhoods) but different economic and institutional conditions demonstrate different types of investment.

3.3 What factors explain spatial patterns of residential investment?

If residential investment were driven primarily by underlying land values, we would expect to see positive correlations between building permits and economic variables, such as existing housing values and household incomes. As a simple exploration of these relationships, Figure 7 shows scatterplots and locally-weighted kernel density regressions for tract-level measures of permits and housing values. The top left graph plots all residential construction permits against tract median house value, while the remaining three graphs break out additions, alterations and new units separately. Baseline tract housing values are positively correlated with permits over the following years, for all permits, additions, and alterations. However, the estimated relationship between housing values and new units is essentially flat. Similar graphs using household income and median rents produce the same patterns: additions and alterations increase with these economic indicators, but new units appear to be uncorrelated with them.

The regression analysis begins with addition permits. Results suggest that the frequency of addition permits reflects underlying economic determinants of land values and housing conditions (Table 6). As the standard redevelopment model predicts, the number of additions is positively associated with existing housing values and the age of existing housing, and is negatively associated with housing density (Column 1). Figure 3 showed more concentration of addition along the city's perimeter, far from the CBD, but regressions do not provide consistent results on proximity to the CBD or to Metro stations, when controlling for other tract characteristics and ANC fixed effects (Columns 2-5). The signs on demographic variables are mostly as expected: more additions occur in high-income, high owner-occupancy tracts. The negative coefficient on educational attainment might be consistent with prior research that highly educated residents tend to oppose neighborhood change, although this is speculative. The coefficients on black and Hispanic population shares are negative and significant in columns 3 and 4, but become insignificant once ANC fixed effects are added (Column 5). Overall, the results are consistent with the hypothesis that building additions are driven by underlying economic factors.

Table 7 shows the same basic model applied to alteration permits (Column 2) and new units (Columns 3-4), with the addition results shown in Column 1 for easy comparison. Alteration permits reflect several of the same factors as additions: they are positively (but weakly significantly) associated with housing values and prior density, as well as the share of owner-occupants. As with additions, alteration permits are negatively associated with housing density, although the coefficient is not significantly different from zero. The R-squared values are quite similar for the addition and alteration regressions, explaining roughly 87 percent of variation in tract-level permits. Results on new units differ in several ways, however. The one consistent predictor of new units is the share of pre-1940 housing, but the direction is the opposite of that predicted by the standard redevelopment model: less new construction occurs in tracts with older housing. The assumption behind the model is that older housing is poorer quality, and thus ripe for replacement. In the DC context, many neighborhoods filled with early-20th century rowhouses fall under historic preservation, so demolition and replacement may be difficult. None of the proxies for land values – housing values, income and demographics – are significant predictors of new housing. Because new units are left-censored at zero (approximately 20% of tracts have no new housing units), Column 4 shows the results of a Tobit estimation, correcting for censoring. The results are qualitatively similar, except that the distance to Metro stations becomes statistically significant (same sign as in Column 3). The R-squared on the OLS estimate of new units is roughly half that of the regressions on addition and alteration permits.

4) Next steps and discussion

Like many other large U.S. cities, Washington DC has experienced strong growth in housing values over the past 25 years, although gains have not been uniformly distributed across space. Much of the city's original housing stock was built during the early 20th century (or before), and is relatively low density, with potentially poor quality and/or outdated structures. Therefore the city offers an interesting empirical setting to the type and quantity of housing investment that may occur in response to rising land values. Administrative data on building permits provide a rich source of information on specific housing investments. Results indicate that additions and alterations to existing structures are more prevalent than ground-up new construction, and that housing investments vary across neighborhoods within the city. Preliminary regressions suggest that the spatial patterns of additions and alterations are generally consistent with standard economic model of redevelopment, but the location of new housing permits is more difficult to predict.

The preliminary results suggest several possible directions for additional work. A more complete categorization of specific activities conducted is currently underway. Changes of interest include popups, bump outs, conversions from one structure type to another, changes in units per building, or enclosures of garages and porches that expand the interior square footage. Other categories include kitchen and bathroom renovations, replacement of doors and windows, new decks/porches, and other interior and exterior renovations. A second extension is to test alternate hypotheses that could systematically predict new construction. Possible factors might include the availability of large land parcels from prior industrial or public uses, or coherence with centrally determined city planning and redevelopment goals. A third direction of interest is to more formally test the roles of zoning and neighborhood politics in shaping or constraining housing investment. Over the observed time period, there have been some zoning changes, as well as within-city differences in zoning. Some ANCs have undertaken temporary or permanent actions to block certain types of investment, notably pop-ups: finer analysis at the parcel level and for shorter time periods might be possible to see whether these are binding constraints.

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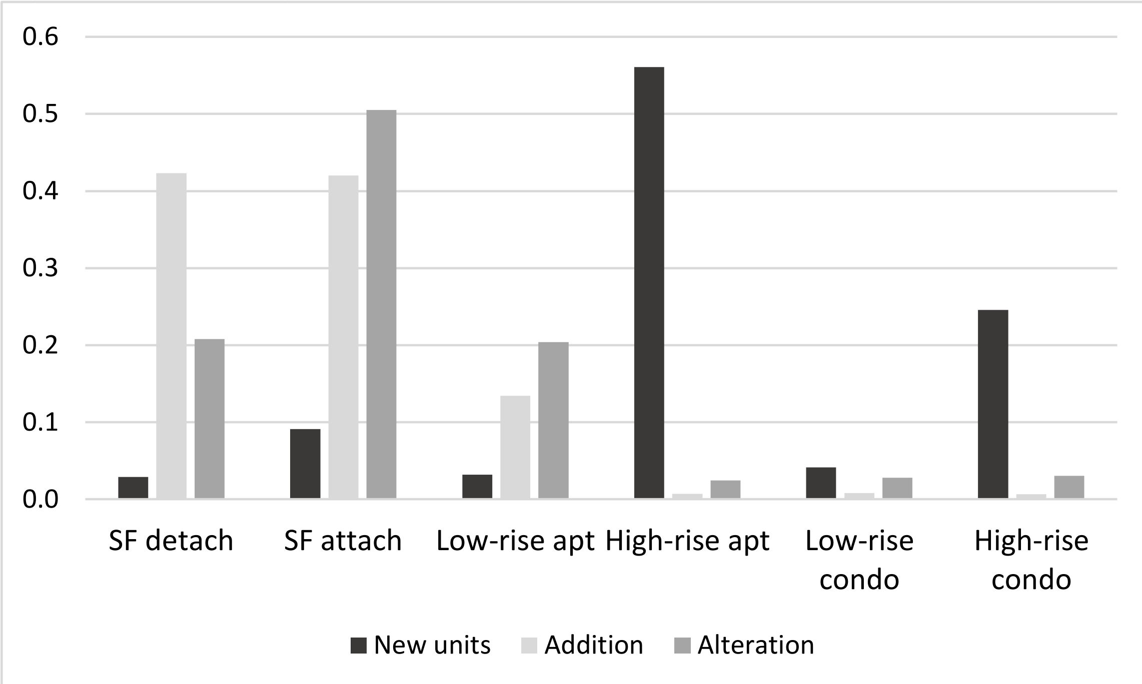
Figure 1: Pop-up and bump-out redevelopments, Columbia Heights, Washington DC

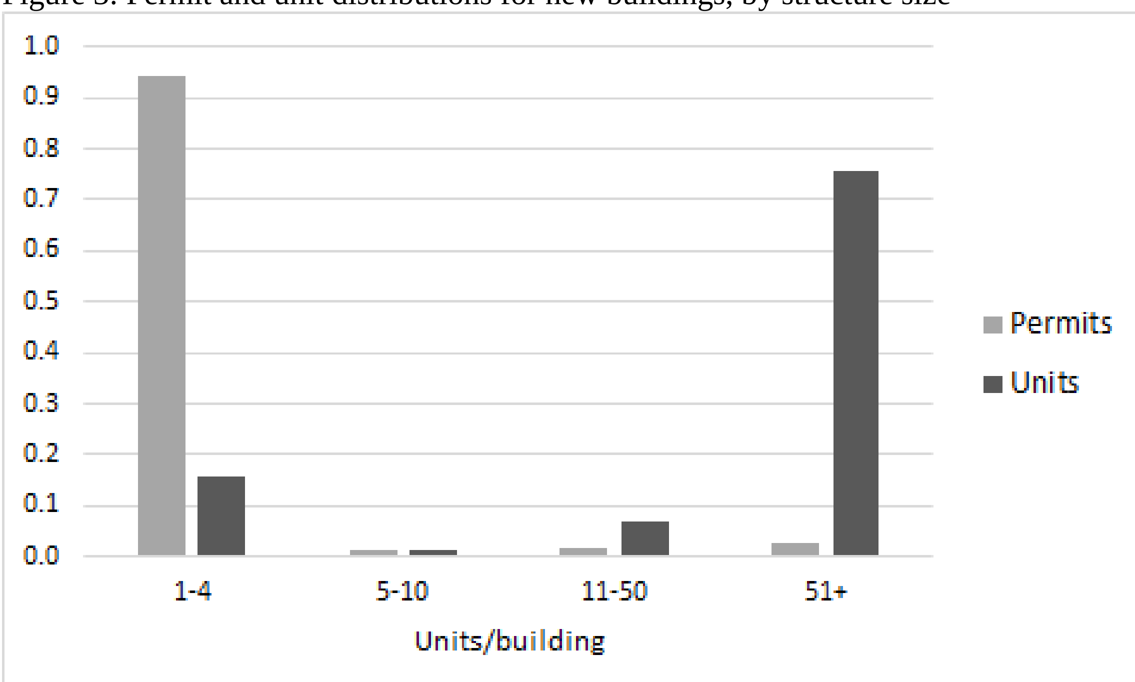
Photos by author, December 2016.

Figure 2: Investment type by structure



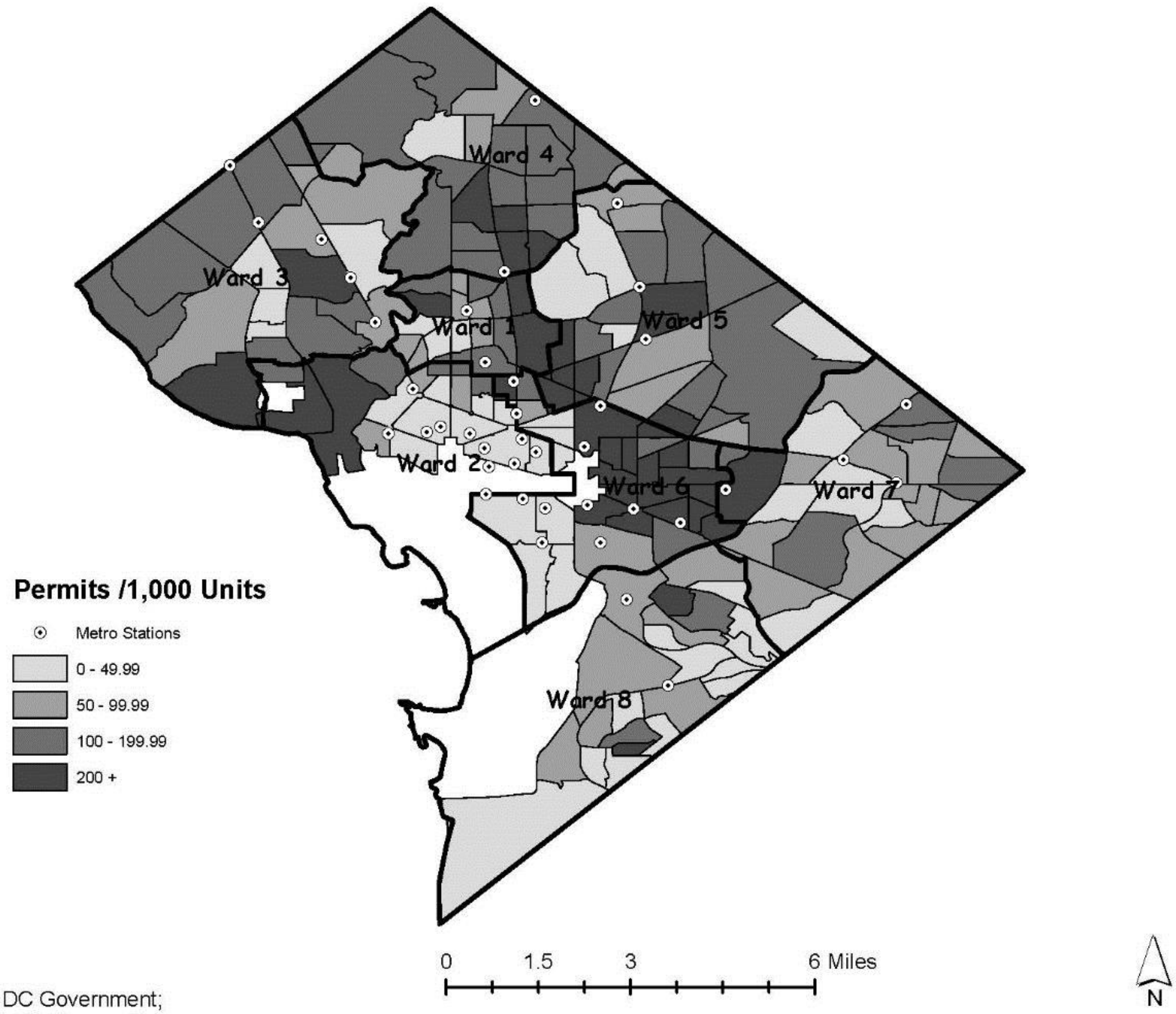
Notes: Share of permits for additions and alternations; share of housing units for new building. Structure types are matched to land use categories from DC administrative data. Condo categories include both condominiums and cooperatives.

Figure 3: Permit and unit distributions for new buildings, by structure size



Notes: Unit counts per building for all residential structures. 1-4 includes single family detached, single-family attached, and small apartment and condo buildings. Structure size groups can be either owner-occupied or renter-occupied.

Figure 4: Alteration permits by census tract, 2008-2016



Sources: opendata.dc.gov, DC Government;
American Community Survey, U.S. Census Bureau

Figure 5: Addition permits by census tract, 2008-2016

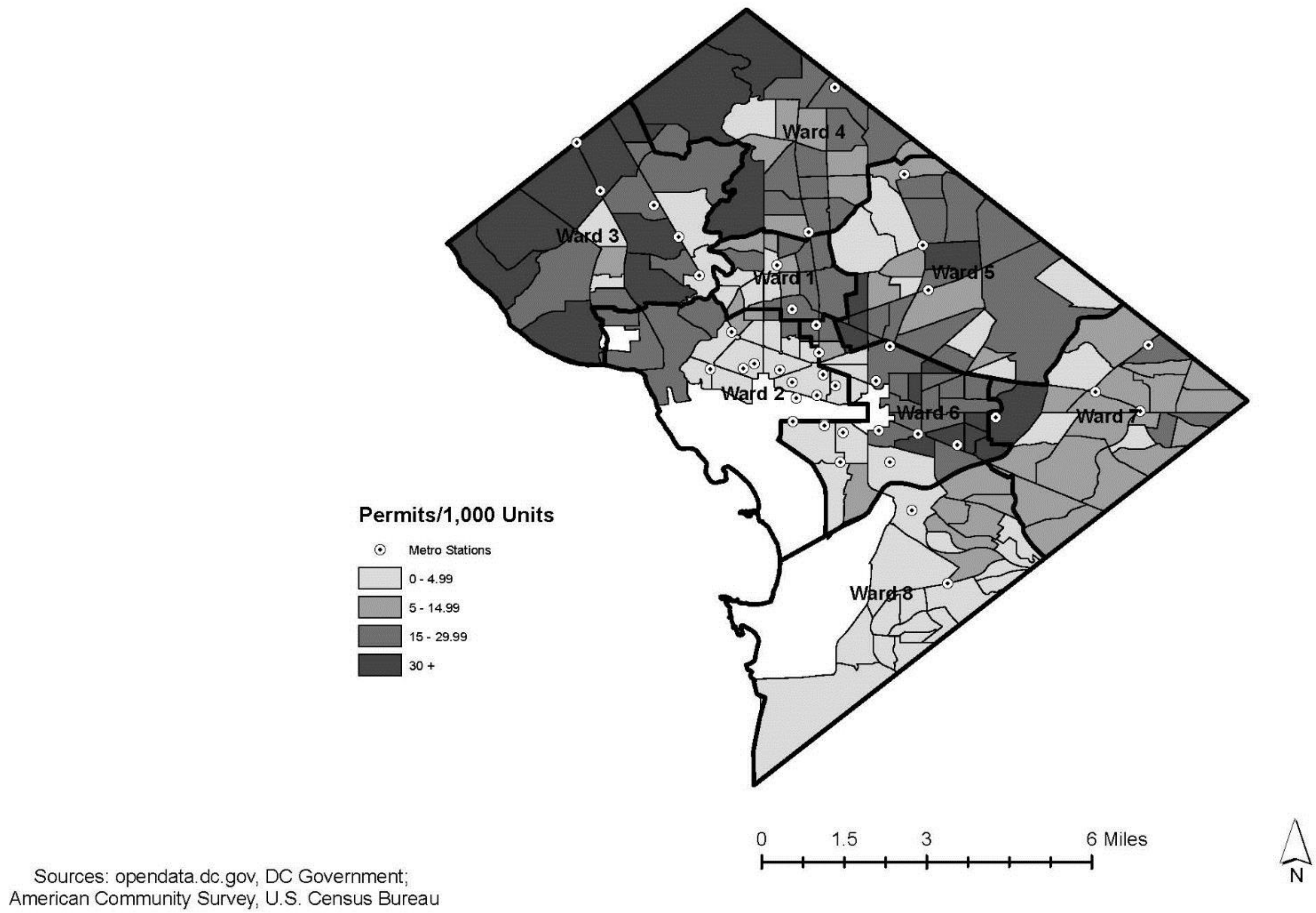


Figure 6: New housing units permitted by census tract, 2008-2016

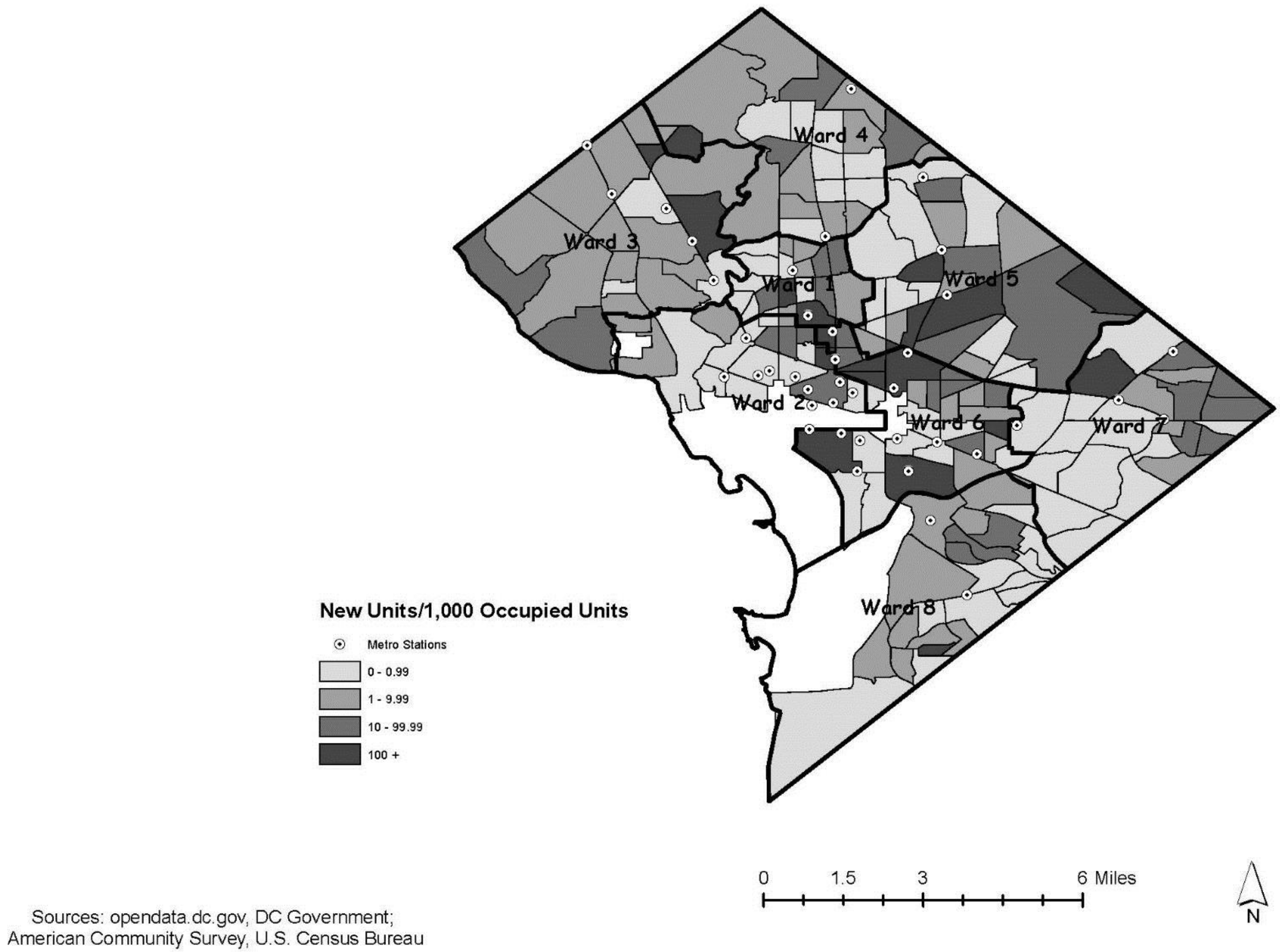


Table 1: Residential building permits by type, 2008-2016

Permit type	Number
New building (permits)	1,635
New building (units)	11,003
Addition	3,928
Alteration	29,414
Other construction	5,890
Total bldg permits	92,772

Source: Author's calculations using DC building permits from opendata.dc.gov

Table 2: Variable definitions and sources

Variable name	Definition	Source
Outcomes		dcopengov, ACS
new units	New units permitted/1000 hsg units	
additions	Addition permits/1000 hsg units	
alterations	Alteration permits/1000 hsg units	
Housing		ACS
hsgvalue	Median value, owner-occupied houses	
rent	Median contract rent	
hsgdens	Housing units/acre	
hsg_age	Median housing age	
fam1_4	1-4 family housing (%)	
Population		ACS
income	Median household income	
baplus	Pop, BA or above (%)	
white	White, non-Hispanic (%)	
black	Black, non-Hispanic (%)	
hisp	Hispanic, all races (%)	
kids	Pop under 18 yrs (%)	
old	Pop 65+ yrs (%)	
Location		
distcbd	Miles to CBD (City Hall)	ACS
dist_sta	Miles to nearest Metro station	WMATA
anc	Area Neighborhood Council	dcopengov

Table 3: Variable summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Outcomes					
new units	176	49.9	182.2	0.0	1744.1
additions	176	14.7	15.0	0.0	74.9
alterations	176	110.6	81.5	2.5	364.7
Housing					
hsgdens	177	8,266	6,819	45	42,700
medvalue	168	432,388	182,717	143,400	924,000
medrent	172	1,068	358	351	2,000
ownocc	176	43.9	22.3	2.0	94.2
hsgpre40	177	35.7	24.0	0.0	100.0
fam1_4	177	54.7	28.1	0.0	100.0
Population					
pop	177	3,377	1,284	1,189	7,436
medinc	177	62,773	35,491	0	213,889
baplus	177	31.3	22.9	1.1	79.6
white	177	31.4	30.5	0.3	87.2
black	177	56.2	35.4	2.4	98.5
hisp	177	8.2	8.2	0.2	43.1
kids	177	17.5	8.7	0.4	40.3
old	177	11.7	6.1	0.5	48.4
Location					
distcbd	177	3.24	1.42	0.39	6.22
diststa	177	0.64	0.39	0.07	2.04

Table 4: Sample descriptions of work

category	desc_of_work
new building	**New Single Family Dwelling** type Hepburn per ZC #06-08 including 8ftx14ft deck
	Convert SFD to two family flat. **Extension** of building at rear. New HVAC systems, new electrical wirings, new bathroom fixtures. New kitchens.
	New Construction of a 5 story Mixed Use Building with commercial Retail on the Ground/1st Floor and **12 Residential Units** on floors 2-5 as per plans.
addition	Two story of **rear addition, kitchen renovation, new bathroom.** Includes mechanical, electrical and plumbing.
	Convert SFD into 2 unit flat with **3rd floor addition** and **rear build out addition**.
	New wood Fence installation,along with new Garage, and **deck addition**
	Conversion of 12 unit rooming house into 3 unit apartment house with **new 3rd story addition**
alteration	**Replace five window**s on third floor front with one-over-one Pella aluminum-clad wood windows to match the color and brick mold of the other windows and to fit the original masonry opening.
	Install roll up door at rear of property on existing fence line. All work on private property.

Table 5: Types of investment created from descriptions of work

Permit category	Variable created
New building	structure
	units_new
	stories_new
	parking
All permits	conversion
Addition, alteration	bumpout
	newstory
	newapt
	newdeck
	interior
	exterior
	kitchenreno
	bathreno
	doors

Table 6: Determinants of addition permits

Dependent var:	Additions/1000 hsg				
	(1)	(2)	(3)	(4)	(5)
lvalue	12.65***			13.97***	8.586***
	(3.013)			(2.751)	(2.303)
ldense	-7.246***			-2.150**	-2.316**
	(1.194)			(0.934)	(1.017)
hsgpre40	0.246***			0.160***	0.137***
	(0.033)			(0.033)	(0.042)
distcbd		0.479		2.088***	1.368
		(0.870)		(0.669)	(1.399)
diststa		4.125		-0.288	-2.277
		(4.484)		(2.064)	(2.077)
linc			15.95***	8.796***	8.604***
			(3.492)	(2.827)	(2.592)
baplus			-0.460***	-0.403***	-0.187**
			(0.098)	(0.099)	(0.086)
ownocc			0.273***	0.151***	0.0903**
			(0.050)	(0.039)	(0.045)
black			-0.216***	-0.154***	0.039
			(0.058)	(0.059)	(0.068)
hisp			-0.245***	-0.288***	-0.144
			(0.082)	(0.084)	(0.111)
ANC fixed?	N	N	N	N	Y
Observations	168	176	175	168	168
R-squared	0.583	0.018	0.593	0.73	0.872

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Determinants of addition, alteration and new construction permits

Dependent var:	Additions	Alterations	New units	New units
	(1)	(2)	(3)	(4)
lvalue	8.586***	28.92*	0.036	0.384
	(2.303)	(14.880)	(0.833)	(1.013)
ldense	-2.316**	-1.536	-0.545	-0.720
	(1.017)	(6.295)	(0.390)	(0.454)
hsgpre40	0.137***	1.944***	-0.0327***	-0.0389***
	(0.042)	(0.239)	(0.012)	(0.013)
distcbd	1.368	-4.949	0.086	0.348
	(1.399)	(6.514)	(0.395)	(0.434)
diststa	-2.277	-1.317	-0.928	-1.521**
	(2.077)	(13.290)	(0.561)	(0.628)
linc	8.604***	21.400	0.589	0.522
	(2.592)	(15.370)	(0.789)	(0.973)
baplus	-0.187**	-0.585	-0.027	-0.025
	(0.086)	(0.604)	(0.029)	(0.034)
ownocc	0.0903**	0.766***	0.006	0.012
	(0.045)	(0.267)	(0.016)	(0.019)
black	0.039	-0.188	-0.002	0.004
	(0.068)	(0.484)	(0.026)	(0.030)
hisp	-0.144	-1.425*	-0.005	0.002
	(0.111)	(0.821)	(0.042)	(0.052)
ANC fixed?	Y	Y	Y	Y
Estimation	OLS	OLS	OLS	Tobit
Observations	168	168	168	168
R-squared	0.872	0.865	0.424	0.1416

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1