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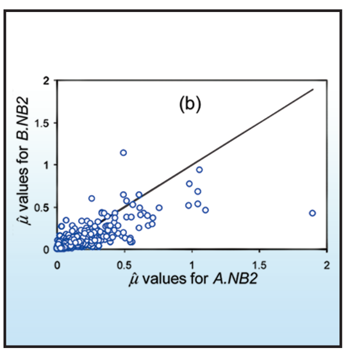
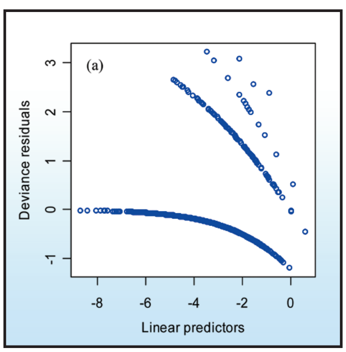
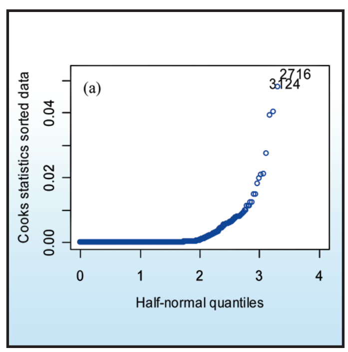
Generalized Linear (Mixed) Models of Post-Earthquake Ignitions

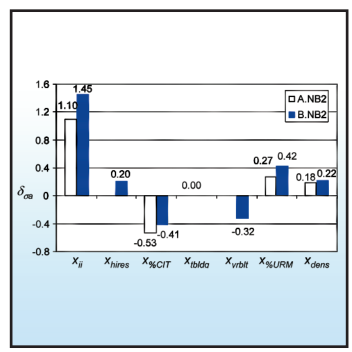
by

Rachel A. Davidson









Technical Report MCEER-09-0004

July 20, 2009

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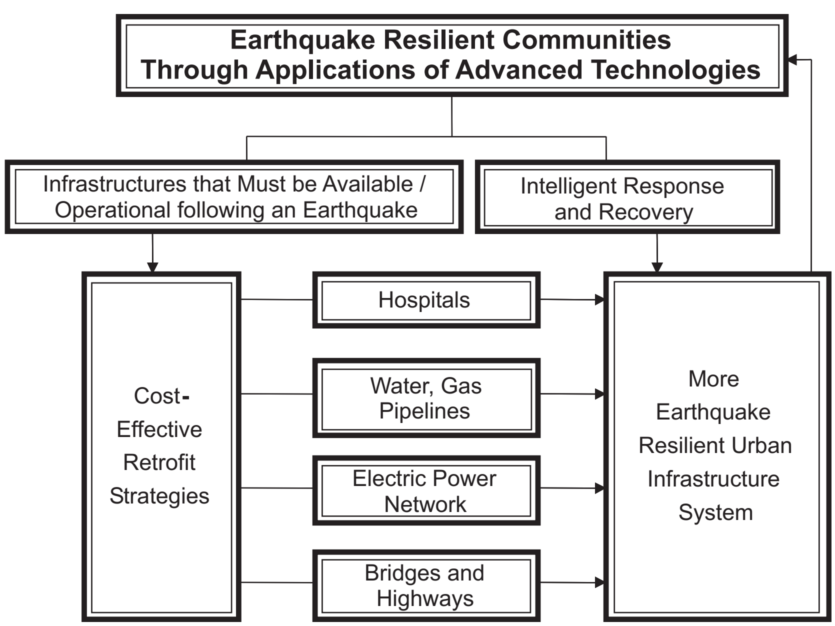
Preface

The Multidisciplinary Center for Earthquake Engineering Research (MCEER) is a national center of excellence in advanced technology applications that is dedicated to the reduction of earthquake losses nationwide. Headquartered at the University at Buffalo, State University of New York, the Center was originally established by the National Science Foundation in 1986, as the National Center for Earthquake Engineering Research (NCEER).

Comprising a consortium of researchers from numerous disciplines and institutions throughout the United States, the Center's mission is to reduce earthquake losses through research and the application of advanced technologies that improve engineering, pre-earthquake planning and post-earthquake recovery strategies. Toward this end, the Center coordinates a nationwide program of multidisciplinary team research, education and outreach activities.

MCEER's research is conducted under the sponsorship of two major federal agencies: the National Science Foundation (NSF) and the Federal Highway Administration (FHWA), and the State of New York. Significant support is derived from the Federal Emergency Management Agency (FEMA), other state governments, academic institutions, foreign governments and private industry.

MCEER's NSF-sponsored research objectives are twofold: to increase resilience by developing seismic evaluation and rehabilitation strategies for the post-disaster facilities and systems (hospitals, electrical and water lifelines, and bridges and highways) that society expects to be operational following an earthquake; and to further enhance resilience by developing improved emergency management capabilities to ensure an effective response and recovery following the earthquake (see the figure below).



A cross-program activity focuses on the establishment of an effective experimental and analytical network to facilitate the exchange of information between researchers located in various institutions across the country. These are complemented by, and integrated with, other MCEER activities in education, outreach, technology transfer, and industry partnerships.

This report presents a comprehensive approach to statistical modeling of post-earthquake ignitions and to data compilation for such modeling, and applies it to present day California. Specifically, regression models are developed that can be used to estimate the number of ignitions per census tract as a function of tract characteristics and the ground shaking experienced in a specified earthquake. The new approach recognizes the discrete nature of ignition counts by using generalized linear and generalized linear mixed models for the first time in this type of application. It includes careful model selection and goodness-of-fit analyses, examines multiple covariates to estimate ignitions, and uses a census tract as a unit of study to enable better estimates at a finer geographic resolution.

ABSTRACT

This report presents a comprehensive approach to statistical modeling of post-earthquake fire ignitions and to data collection for such modeling, and applies it to present day California. Generalized linear and generalized linear mixed models (GLMs and GLMMs) are used for this application for the first time. The approach recognizes that ignition counts are discrete, examines many possible covariates, and uses a small unit of study to ensure homogeneity in variable values for each area unit. Two datasets were developed to explore the effect of missing ignition data, each with a different assumption about the missing data. For one dataset, the recommended model includes instrumental intensity; percentage of land area that is commercial, industrial, or transportation; total building area; percentage of building area that is unreinforced masonry; and people per sq. km. The other includes the same, except area of high-intensity residential development replaces total building area, and median year built over all housing units is also included. The models should be useful in estimating the number and locations of post-earthquake ignitions in future earthquakes.

Subject headings: California, earthquakes, fire hazards, geographic information systems, regression models, statistical models

ACKNOWLEDGMENTS

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SECTION 1

INTRODUCTION

Post-earthquake fires can be a significant collateral hazard associated with earthquakes. They were a dominant cause of losses in the 1906 San Francisco earthquake and an important factor in the 1989 Loma Prieta earthquake. Computer models of post-earthquake fires can be valuable tools to help estimate the impacts of future earthquakes and plan for them. They were employed, for example, to demonstrate the need for and guide major improvements in San Francisco's Auxiliary and Portable Water Supply Systems (Scawthorn et al. 2006). Post-earthquake fire models can be divided into two main modules—ignition and spread/suppression. This report focuses on the former.

Because there are so many possible ignition mechanisms and there is so much inherent variability in the phenomenon, almost all previous post-earthquake ignition models are statistical. (Mohammadi et al. (1994) and Williamson and Groner (2000), which use event and fault trees, are exceptions.) Models typically regress some measure of ignition rate on some measure of earthquake intensity (e.g., ignitions per sq. ft. of building area vs. peak ground acceleration, PGA). Scawthorn et al. (2005), Li et al. (2001), and Zhao et al. (2006) then simulate ignitions for each area unit assuming they follow a Poisson process with the ignition rate from the regression. Ren and Xie (2004) estimate the number of ignitions in each area unit as the product of ignition rate from the regression and total building area of the unit. Cousins and Smith (2004) assume ignitions are normally distributed with mean ignition rate from the regression and a standard deviation of one. Lee et al. (2007) reviews the literature on post-earthquake ignition and spread/suppression modeling. Scawthorn et al. (2005) offers an excellent overview of post-earthquake fires, including discussion of historical post-earthquake fires and causes of post-earthquake ignitions.

Though often not explicitly discussed, it appears that previous regression models were fit using least squares estimation. Several authors report an R^2 value (Lee et al. 2007), but details of the model fitting and final goodness-of-fit are omitted. Further, none of the available models explore the possibility of using more than one covariate to estimate ignition rate. Previous studies also typically provide little information about the data used to fit the models. Only a few sources specifically define which ignitions are considered (e.g., only structural fires that occurred within 3 days of the earthquake). They all use cities or other relatively large units of study within which many covariate values are likely not constant. Most sources do not specify how it was decided which cities to include in the dataset. Was it only those that reported ignitions (therefore ignoring zero counts), or all cities with at least a specified level of ground shaking? In the analogous context of vehicle accident models, Miaou and Lum (1993) examine the limitations of linear regression of the type used in previous post-earthquake ignition models.

This report presents a comprehensive approach to statistical modeling of post-earthquake ignitions and to data compilation for such modeling, and applies it to present day California. Specifically, regression models are developed that can be used to estimate the number of ignitions per census tract as a function of tract characteristics and the ground shaking experienced in a specified earthquake. The new approach recognizes the discrete nature of ignition counts by using generalized linear and generalized linear mixed models (GLMs and GLMMs) for the first time for this application. It includes careful model selection and goodness-of-fit analyses, examines multiple covariates to estimate ignitions, and uses a small unit of study—census tract. The data and data collection process are described in Section 2, followed by background on the models used in Section 3. The model selection process and the final recommended models are discussed in Sections 4 and 5, respectively.

SECTION 2

DATA DESCRIPTION

2.1. Data Compilation

By overlaying data from several sources in a geographic information system (GIS), a database was compiled that includes a value for each variable in Table 2-1 for each observation, where an observation is a 1990 census tract in a specified earthquake. It also includes an earthquake indicator (x_{eq}) for each observation. Census tracts were chosen as the unit of study to help ensure that covariate values are relatively homogeneous within them, because population is roughly constant across tracts, and because data for many covariates were available by census tract. Only data from six recent California earthquakes (1983 to 1994) were included since characteristics of the built environment (e.g., vulnerability of gas systems, building structural types) and cultural factors (e.g., what type of appliances are used and when) may make data from other countries or from long ago inconsistent.

Ideally, for each earthquake, the data would include an observation for every census tract that experienced ground shaking and therefore could potentially have experienced ignitions. Unfortunately, ignition data are only available (i.e., were only collected) for selected jurisdictions for each earthquake. Two datasets were developed to explore the possible effect of missing ignition data. For a given earthquake, Dataset A includes only those census tracts that experienced a nonzero PGA and that are in a jurisdiction for which ignition data were available (Table 2-1). Dataset B assumes that tracts that experienced nonzero PGA but are not in jurisdictions we have data for are zero counts (Table 2-2). Both datasets include the same covariates. Table 2-3 indicates the jurisdictions for which data are available, by earthquake.

Table 2-1. Descriptive Statistics of Continuous Variables Considered in Ignition Model (Dataset A)

	Variable	Min.	Mean	Median	St. dev.	Max
y	1. Number of ignitions	0.000	0.045	0.000	0.244	4.000
x_{pga}	2. PGA, g	0.060	0.208	0.180	0.128	0.800
x_{pgv}	3. PGV, cm/s	2.000	16.753	11.000	16.466	156.000
x_{sa}	4. $S_{a(0.3)}$, g	0.000	0.460	0.380	0.309	2.220
x_{ii}	5. Instrumental intensity	4.233	6.248	6.100	0.976	9.900
t_{bldg}	6. Total building area, sq m	18.1	277.7	244.7	164.1	2459.0
x_{rbldg}	7. Residential building area, sq m	0.0	216.0	202.0	93.0	958.1
x_{cbldg}	8. Commercial building area, sq m	0.0	46.2	19.7	102.4	2131.0
x_{ibldg}	9. Industrial building area, sq m	0.0	11.3	2.0	38.4	645.8
$x_{\%rbldg}$	10. % building area that is residential	0.0%	82.8%	88.8%	17.5%	100.0%
$x_{\%cbldg}$	11. % building area that is commercial	0.0%	12.9%	8.6%	13.0%	98.4%
$x_{\%ibldg}$	12. % building area that is industrial	0.0%	2.9%	0.8%	6.0%	56.0%
x_{wood}	13. Wood building area, sq m	3.27	207.67	192.08	94.02	929.36
x_{steel}	14. Steel building area, sq m	0.08	15.01	8.05	26.98	515.31
x_{con}	15. Concrete building area, sq m	0.12	15.53	9.47	23.45	434.92
x_{precon}	16. Prestressed concrete building area, sq m	0.00	13.16	5.19	30.59	469.38
x_{RM}	17. Reinforced masonry building area, sq m	0.58	18.53	11.55	27.51	504.99
x_{URM}	18. Unreinforced masonry building area, sq m	0.02	4.43	2.78	6.57	118.18
x_{MH}	19. Mobile home building area, sq m	0.00	3.41	0.11	11.38	165.94
$x_{\%wood}$	20. % building area that is wood	12.1%	78.1%	81.9%	15.4%	98.5%
$x_{\%steel}$	21. % building area that is steel	0.1%	4.6%	3.5%	3.8%	31.7%
$x_{\%con}$	22. % building area that is concrete	0.1%	5.0%	4.2%	3.6%	28.1%
$x_{\%precon}$	23. % building area that is prestressed concrete	0.0%	3.7%	2.3%	4.2%	33.3%
$x_{\%RM}$	24. % building area that is reinforced masonry	1.1%	5.9%	5.0%	3.7%	35.4%
$x_{\%URM}$	25. % building area that is unreinforced masonry	0.0%	1.4%	1.3%	1.0%	5.4%
$x_{\%MH}$	26. % building area that is mobile homes	0.0%	1.2%	0.0%	4.2%	57.7%
x_{W1}	27. W1 building area with ≥ slight damage,[a] sq m	0	22,028	8,691	29,167	178,138
x_{C2L}	28. C2L building area with ≥ slight damage,[a] sq m	0	1,255	311	2,912	43,194
x_{RM1L}	29. RM1L building area with ≥ slight damage,[a] sq m	0	1,516	440	3,181	45,579
$x_{\%W1}$	30. % W1 building area with ≥ slight damage[a]	0.0%	17.6%	8.6%	19.9%	73.8%
$x_{\%C2L}$	31. % C2L building area with ≥ slight damage[a]	0.0%	21.9%	9.7%	25.4%	89.7%
$x_{\%RM1L}$	32. % RM1L building area with ≥ slight damage[a]	0.0%	17.4%	8.2%	20.6%	79.1%
x_{yrblt}	33. Median year built over all housing units	1939	1959	1958	11.2	1989
$x_{\%pre70}$	34. % housing units built pre-1970	0.0%	69.6%	75.2%	23.3%	100.0%
x_{OHU}	35. Num. occupied housing units (OHUs)	0	1465	1423	1034	11063
x_{gas}	36. Num. OHUs with gas house heating[b]	0	1195	1189	830	9761
x_{elec}	37. Num. OHUs with electricity house heating	0	243	135	340	4529
$x_{\%gas}$	38. % OHUs with gas house heating[b]	0.0%	70.4%	83.7%	32.1%	100.0%
$x_{\%elec}$	39. % OHUs with electricity house heating	0.0%	12.7%	9.3%	12.8%	100.0%
x_{pop}	40. Number of people	5	5,241	4,844	2,607	36,034
x_{dens}	41. People per sq. km.	0	4,457	3,445	4,048	39,018
x_{area}	42. Tract area, millions of sq m	0.0106	10.48	1.32	185.20	9,973.4
x_{lowres}	43. Low-intensity residential area, sq m	0	292,915	251,100	233,075	3.007M
x_{hires}	44. High-intensity residential area, sq m	0	128,594	102,600	130,365	2.461M
x_{CIT}	45. Commercial, industrial, transportation area, sq m	0	59,005	37,800	91,097	1.434M
$x_{\%lowres}$	46. % land area that is low-intensity residential	0.0%	18.9%	19.0%	10.5%	85.3%
$x_{\%hires}$	47. % land area that is high-intensity residential	0.0%	8.9%	7.2%	7.2%	46.1%
$x_{\%CIT}$	48. % land area that is commercial, industrial, or transportation	0.0%	2.8%	2.7%	1.6%	18.0%

[a] W1 = wood, light-frame <5,000 ft^2, C2L = 1-3 story concrete shear wall, RM1L = 1-3 story reinforced masonry bearing walls with wood or metal deck diaphragms

[b] Gas includes utility, bottled, tank, or liquid petroleum gas, oil, kerosene.

Table 2-2. Descriptive Statistics of Continuous Variables Considered in Ignition Model (Dataset B)

	Variable	Min.	Mean	Median	St. dev.	Max
y	1. Number of ignitions	0.000	0.019	0.000	0.158	4.000
x_{pga}	2. PGA, g	0.020	0.160	0.120	0.117	0.800
x_{pgv}	3. PGV, cm/s	1.000	13.92	9.000	14.183	156.000
x_{sa}	4. $S_{a(0.3)}$, g	0.000	0.326	0.280	0.303	2.220
x_{ii}	5. Instrumental intensity	0.000	5.899	5.800	1.087	9.900
t_{bldg}	6. Total building area, sq m	0.762	301.1	264.6	177.3	2696.0
x_{rbldg}	7. Residential building area, sq m	0.0	206.6	202.2	130.7	1399.7
x_{cbldg}	8. Commercial building area, sq m	0.0	39.7	16.4	89.6	2131.0
x_{ibldg}	9. Industrial building area, sq m	0.0	10.4	1.5	38.3	838.1
$x_{\%rbldg}$	10. % building area that is residential	0.0%	72.9%	87.2%	32.0%	100.0%
$x_{\%cbldg}$	11. % building area that is commercial	0.0%	10.9%	6.7%	13.3%	98.4%
$x_{\%ibldg}$	12. % building area that is industrial	0.0%	2.5%	0.6%	7.2%	56.0%
x_{wood}	13. Wood building area, sq m	0.59	231.21	212.24	113.67	1364.61
x_{steel}	14. Steel building area, sq m	0.03	14.72	7.63	28.70	674.02
x_{con}	15. Concrete building area, sq m	0.04	14.63	8.87	22.13	434.92
x_{precon}	16. Prestressed concrete building area, sq m	0.00	13.10	5.08	31.67	558.37
x_{RM}	17. Reinforced masonry building area, sq m	0.05	18.01	11.40	25.98	504.99
x_{URM}	18. Unreinforced masonry building area, sq m	0.01	4.11	2.46	6.20	118.18
x_{MH}	19. Mobile home building area, sq m	0.00	5.34	0.23	14.47	354.63
$x_{\%wood}$	20. % building area that is wood	12.1%	79.4%	83.4%	15.3%	98.7%
$x_{\%steel}$	21. % building area that is steel	0.0%	4.2%	3.1%	3.8%	31.7%
$x_{\%con}$	22. % building area that is concrete	0.0%	4.5%	3.6%	3.5%	29.0%
$x_{\%precon}$	23. % building area that is prestressed concrete	0.0%	3.4%	2.0%	4.1%	33.3%
$x_{\%RM}$	24. % building area that is reinforced masonry	1.0%	5.4%	4.5%	3.6%	35.4%
$x_{\%URM}$	25. % building area that is unreinforced masonry	0.0%	1.2%	1.0%	0.9%	5.4%
$x_{\%MH}$	26. % building area that is mobile homes	0.0%	1.8%	0.0%	4.9%	78.5%
x_{W1}	27. W1 building area with ≥ slight damage,[a] sq m	0	14,888	3,727	26,204	239,973
x_{C2L}	28. C2L building area with ≥ slight damage,[a] sq m	0	748	115	2,208	43,194
x_{RM1L}	29. RM1L building area with ≥ slight damage,[a] sq m	0	944	196	2,483	47,478
$x_{\%W1}$	30. % W1 building area with ≥ slight damage[a]	0.0%	11.0%	2.8%	17.1%	76.8%
$x_{\%C2L}$	31. % C2L building area with ≥ slight damage[a]	0.0%	13.6%	3.6%	21.7%	92.1%
$x_{\%RM1L}$	32. % RM1L building area with ≥ slight damage[a]	0.0%	10.9%	3.0%	17.5%	83.3%
x_{yrblt}	33. Median year built over all housing units	1939	1962	1962	11.7	1989
$x_{\%pre70}$	34. % housing units built pre-1970	0.0%	63.8%	69.5%	26.0%	100.0%
x_{OHU}	35. Num. occupied housing units (OHUs)	0	1657	1558	1008	11063
x_{gas}	36. Num. OHUs with gas house heating[b]	0	1329	1260	824	9761
x_{elec}	37. Num. OHUs with electricity house heating	0	290	187	332	4529
$x_{\%gas}$	38. % OHUs with gas house heating[b]	0.0%	75.6%	83.1%	23.9%	100.0%
$x_{\%elec}$	39. % OHUs with electricity house heating	0.0%	15.5%	12.6%	12.9%	100.0%
x_{pop}	40. Number of people	5	5,371	4,893	2,875	36,034
x_{dens}	41. People per sq. km.	0.3	3,340	2,622	3,458	39,018
x_{area}	42. Tract area, millions of sq m	0.005	30.47	1.80	221.56	9,973.4
x_{lowres}	43. Low-intensity residential area, sq m	0	311,580	257,400	262,549	3.007M
x_{hires}	44. High-intensity residential area, sq m	0	117,767	89,100	128,360	2.461M
x_{CIT}	45. Commercial, industrial, transportation area, sq m	0	69,638	42,300	107,882	2.479M
$x_{\%lowres}$	46. % land area that is low-intensity residential	0.0%	15.5%	15.3%	10.8%	85.3%
$x_{\%hires}$	47. % land area that is high-intensity residential	0.0%	6.0%	4.1%	6.1%	46.1%
$x_{\%CIT}$	48. % land area that is commercial, industrial, or transportation	0.0%	2.4%	2.3%	1.7%	18.0%

[a] W1 = wood, light-frame <5,000 ft^2, C2L = 1-3 story concrete shear wall, RM1L = 1-3 story reinforced masonry bearing walls with wood or metal deck diaphragms

[b] Gas includes utility, bottled, tank, or liquid petroleum gas, oil, kerosene.

Table 2-3. Earthquakes and Jurisdictions Included

Earthquake	Date and time	Cities and counties for which data are available	Num. ignitions in dataset	Num. observations	
				with PGA>0	with data available
Coalinga	May 2, 1983, 16:42	Coalinga	3	416	3
Morgan Hill	April 24, 1984, 13:15	Morgan Hill, San Jose, Saratoga	6	1,481	20
N. Palm Springs	July 8, 1986, 02:21	Palm Springs, Riverside County, Idyllwild	1	167	76
Whittier Narrows	October 1, 1987, 07:42	Los Angeles, Los Angeles County, Pasadena, San Marino, Alhambra, Montebello	20	2,243	1,616
Loma Prieta	October 17, 1989, 17:04	San Francisco Oakland Santa Cruz Berkeley	34 0 1 1	1,149	283
Northridge	January 17, 1994, 04:30	Los Angeles Santa Monica Orange County	77 4 1	2,462	1,215
		Total	148	7,918	3,213

Dataset A likely underestimates the number of observations with zero ignitions because the tracts that are omitted probably have higher proportions of zeros than those that are included. Dataset B likely overestimates the zero counts because there may actually be some unrecorded ignitions among the added tracts. In Dataset A, there are 2,476 census tracts and 8 counties represented in 3,213 observations (census tract-earthquake combinations); in Dataset B, there are 4,369 census tracts and 29 counties in 7,920 observations. The number of observations for Datasets (A; B) are, by earthquake: 1983 Coalinga (3; 416), 1984 Morgan Hill (20; 1,483), 1986 North Palm Springs (76; 167), 1987 Whittier Narrows (1,620; 2,243), 1989 Loma Prieta (284; 1,149), and 1994 Northridge (1,219; 2,462).

2.2. Data Sources

Ignition data were obtained from earthquake-specific reconnaissance reports (Scawthorn and Donelan 1984, Scawthorn et al. 1985, EERI 1986, Wiggins 1988, City of San Francisco 1989, Mohammadi et al. 1992, Olson et al. 2003, Scawthorn et al. 1998, and Orange County Fire Authority, unpublished incident reports from January 1994). Reported street addresses were used to geocode ignitions. A major effort was made to collect additional ignition data from the National Fire Incident Report System (NFIRS) database and by contacting 29 local fire departments. Unfortunately, only data for Orange County in the Northridge earthquake were added as a result of this effort since records did not go back far enough in general. In future earthquakes, however, NFIRS and local fire departments could offer useful sources of ignition data. The datasets include 148 ignitions in 127 observations (Appendix A).

To be consistent, the datasets include only those ignitions that: (1) became structural fires, (2) required fire department help to extinguish, (3) occurred within 10 days of the earthquake, and (4) were identified as earthquake-related. Structural fires that require fire department help to suppress are the ones of primary interest and for which data are available. However, ground shaking and other covariates are probably more related to the total number of ignitions (including smaller structural fires, and electric pole and other non-structural fires) whether they subsequently grew or spread or not. Focusing on structural fires requiring fire department help, therefore, entails an implicit assumption that they make up a constant proportion of all ignitions, a reasonable assumption if future earthquakes are of similar severity as past ones. Many data sources did not indicate the number of days post-earthquake during which ignitions were considered, and the Whittier Narrows ignitions did not have times associated with them, so it is difficult to establish exactly what time cutoff this dataset represents. One ignition is included that occurred as late as 10 days after the earthquake, but most occurred within 3 days. Non-earthquake-related ignitions were not included here because: (1) most data sources do not include them, (2) theoretically, ground motion and building damage should be more directly related to just earthquake-related ignitions, and (3) if desired, ignitions based on normal, non-earthquake ignition rates could be added separately to correctly represent the total number of fires the fire department actually has to suppress.

Appendix A lists the final set of ignitions, and for each, includes its street address, latitude and longitude, time of occurrence, and notes about the process of geocoding it. It also notes any ignitions that were mentioned in the sources but were not included in this study, and explains why they were omitted. While it is believed that most ignitions are included and have been located in the correct census tract, as always the subsequent statistical analysis should be interpreted keeping in mind the level of precision in the input data.

Ground motion data, in terms of PGA, peak ground velocity (PGV), spectral acceleration (S_a at 0.3 s with 5% damping), and instrumental intensity, were obtained from the U.S. Geological Survey Shakemap archives (Wald et al. 2006) (Table 2-1, variables 2 to 5). Table 2-4 defines instrumental intensity. Measured on a scale of I to X+, for values lower than V instrumental intensity depends on PGA, for V to VII it depends on a linear combination of PGA and PGV, and above VII, it depends on PGV (Wald et al. 2006). When a tract experienced multiple ground shaking levels, the average was used.

Building floor area data (Table 2-1, variables 6 to 26) were taken from the default database that comes with HAZUS-MH MR2, the standardized national multi-hazard loss estimation software developed by the Federal Emergency Management Agency (FEMA 2003). Building damage data (Table 2-1, variables 27 to 32) were obtained by running deterministic

HAZUS-MH MR2 analyses with the default database, assuming repeats of the relevant historic earthquakes. For simplicity, only three of the 36 structural types in HAZUS-MH MR2 were used to represent the degree of building damage: light-frame wood <5,000 ft^2 (W1), 1- to 3-story concrete shear wall (C2L), 1- to 3-story reinforced masonry bearing walls with wood or metal deck diaphragms (RM1L). Since HAZUS-MH MR2 is based on 2000 census tracts, these data had to be mapped to 1990 census tracts. The 1990 census provided the building age and heating attributes, population data, and total census tract land area (Table 2-1, variables 33 to 42) (U.S. Census Bureau 1992).

Table 2-4. ShakeMap Instrumental Intensity Scale Definition (Source: Wald et al. 2006)

Perceived shaking	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
Potential damage	None	None	None	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
Peak acceleration (%g)	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
Peak velocity (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	9.1-16	16-31	31-60	60-116	>116
Instrumental intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+

National Land Cover Data (NLCD) was obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium. The data, which are based on MRLC's Landsat 5 Thematic Mapper satellite data and ancillary sources, indicate the land cover class of each 30 m by 30 m grid cell in the coterminous U.S. (MRLC 2001). The three classes related to developed areas—low-intensity residential, high-intensity residential, and commercial/industrial/transportation—were included (Table 2-1, variables 43 to 48).

2.3. Initial Data Analysis

An initial analysis of the datasets was conducted to become familiar with the data, and identify outliers, data-entry errors, or unusual distributions. Tables 2-1, 2-2, and 2-5 provide tabular summaries of the data. Appendix B includes additional graphical summaries and correlation matrices. In a few cases data entry or similar errors were found and corrected. In others, outliers and skewed distributions were noted but no errors were found, so no changes were made. The covariate vs. number of ignition plots offer preliminary ideas about which covariates might be significant (Figures B-3 and B-4). Relationships between each of the ground shaking covariates and the number of ignitions are apparent, for example. In interpreting those figures, however, it is important to note that there are only 14, 2, and 1 observation(s) for 2, 3, and 4 ignition counts, respectively.

Table 2-5. Ignition Counts by Earthquake

Earthquake	Ignition counts					
	(Dataset A) 0	(Dataset B) 0	1	2	3	4
Coalinga	2	415	0	0	1	0
Loma Prieta	251	1,117	28	4	0	0
Morgan Hill	15	1,478	4	1	0	0
N. Palm Springs	75	166	1	0	0	0
Northridge	1,147	2,394	57	9	1	1
Whittier Narrows	1,596	2,223	20	0	0	0
Total	3,086	7,793	110	14	2	1

Examining the correlation matrix for each dataset revealed correlations among several covariates (Appendix B, Tables B-1 and B-2). The correlations given in this discussion are for Dataset A, but the same conclusions were reached for Dataset B. All four ground motion covariates are highly correlated (ρ>0.84). Total building area is highly correlated with all structural types except mobile homes (ρ>0.75). The percentage of the building area that is residential is positively correlated with the percentage that is wood (ρ=0.89), and negatively correlated with the percentages that are commercial (ρ=-0.93), industrial (ρ=-0.69), or any structural type other than mobile homes (ρ>0.83). The percentage of building area that is commercial is positively correlated with all structural types except wood and mobile homes (ρ>0.66). The three percentage damage covariates are extremely correlated (ρ>0.99). Pre-1970 buildings and median year built are negatively correlated (ρ=-0.87). The total number of occupied housing units (OHUs) is correlated with the number with gas (ρ=0.95) or electric heat (ρ=0.68). The number and percentage of OHUs with gas heat are correlated (ρ=0.80), as they are for electric heat (ρ=0.80). The three land area types—low-intensity residential, high-intensity residential, and commercial/industrial/transportation—are correlated (ρ>0.61).

SECTION 3

STATISTICAL MODELS

3.1. Poisson Generalized Linear Model

A Poisson regression model, a type of generalized linear model (GLM), is often used when the response variable measures the number of occurrences (counts) of some random event in a specified unit of space or time (Cameron and Trivedi 1998). Poisson regression is appropriate when counts are nonnegative and discrete, occur due to an underlying stochastic process, and are independent between units conditional on that underlying occurrence rate (i.e., when the response variable can be assumed to be a Poisson distributed random variable). In this case, the number of ignitions, y_i, that occur in observation *i* (where an observation is one census tract in a particular earthquake) is assumed to be a Poisson random variable with parameter μ_i and density:

$$f(y_i \mid \vec{x}_i) = \frac{e^{-\mu_i} \mu_i^{y_i}}{y_i!}, \qquad y_i = 0, 1, 2, \ldots \tag{1}$$

In a Poisson regression model, the parameter μ_i is estimated as a function of a vector of covariates, $\vec{x}_i$, that describe observation *i* and a vector of parameters $\vec{\beta}$ estimated from data:

$$\ln \mu_i = \vec{x}_i^T \vec{\beta} \tag{2}$$

The log "link" function in Eq. 2 ensures that μ_i will be nonnegative. The Poisson regression model is widely used, but it is based on the relatively restrictive assumption that the conditional mean and conditional variance of the count data are equal:

$$Var[y_i \mid \vec{x}_i] = E[y_i \mid \vec{x}_i] = \mu_i \tag{3}$$

This assumption is not valid for many datasets. Often data are overdispersed, meaning the conditional variance is greater than the conditional mean. In fact, data may be inconsistent with the Poisson assumption in many other ways too, such as, truncation and censoring, excess zeros, multimodality, trends, or dependence among event counts (Cameron and Trivedi 1998). Several alternative models, including those discussed in Sections 3.2 and 3.3, can be used if the Poisson model is inadequate. Note that in this analysis, zero-inflated models were not considered appropriate because all observations could have experienced ignitions (i.e., there were not two distinct identifiable processes).

3.2. Negative Binomial Generalized Linear Model

In negative binomial regression, the most common model to account for overdispersion, count data are assumed to follow a negative binomial probability density function instead of a Poisson:

$$f(y_i \mid \mu_i, \alpha) = \frac{\Gamma(y_i + \alpha^{-1})}{\Gamma(y_i + 1)\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu_i} \right)^{\alpha^{-1}} \left(\frac{\mu_i}{\alpha^{-1} + \mu_i} \right)^{y_i}, \quad \alpha \geq 0, \ y = 0, 1, 2, \ldots \tag{4}$$

where $\mu_i = \exp(\vec{x}_i^T \vec{\beta})$, as with the Poisson, and α is the overdispersion parameter. In the negative binomial model (referred to as NB), count data are assumed to have mean μ_i and variance:

$$Var[y_i \mid \vec{x}_i] = \mu_i + \alpha \mu_i^2 \tag{5}$$

Since $\alpha \geq 0$, one feature of the NB model is that it has a higher conditional variance than the Poisson (reducing to the Poisson when $\alpha=0$). The NB also has a larger proportion of zero counts and a thicker right tail than the Poisson (Cameron and Trivedi 1998). The NB can be derived in a few ways, one of which is as a Poisson-Gamma mixture. The counts are treated as conditionally Poisson($\tilde{\mu}_i$), but the Poisson mean $\tilde{\mu}_i$ is treated as stochastic, specifically as the product of the Poisson mean μ_i and a gamma-distributed random variable with mean one and variance α

(Cameron and Trivedi 1998). The NB is thus often interpreted as a Poisson in which the individual observations differ randomly in a way not accounted for by the covariates $\vec{x}_i$, perhaps as a result of omitted covariates or additional randomness.

3.3. Generalized Linear Mixed Model

An alternative method is to use generalized linear mixed models (GLMMs), which are GLMs with random effects. The Poisson GLMM assumes that the conditional distribution of counts is Poisson, as in Eq. 1, but it adds a random term u_k to the link function:

$$\ln \mu_i = \vec{x}_i^T \vec{\beta} + u_k \tag{6}$$

The u_k terms are generally assumed to be either independent normally distributed random variables with mean zero and standard deviation of σ_u, or multivariate normal random variables with covariance matrix Σ. The covariance matrix can be used, for example, to represent spatial correlation. While the NB model has one additional parameter to capture extra-Poisson variability, a GLMM has one for each random term.

SECTION 4

MODEL SELECTION

4.1. Model Selection Process

A careful model selection process was followed for both Datasets A and B. It began with the Poisson GLM, the simplest model, and then was repeated for the alternative models to examine if they provided better fits. All models were fit using *R* software (R Development Core Team 2007). Poisson models, negative binomial models, and GLMMs were fit using the "glm" (*stats*), "glm.nb" (*MASS*), and "lmer" (*lme4*) and "glmmML" (*glmmML*) commands (in the noted libraries), respectively.

Models were evaluated and compared using: (1) the deviance pseudo-R-squared, R^2_{dev}, (2) the NB overdispersion parameter, α, and (3) a pseudo-R-squared based on α, R^2_{α}, (4) likelihood ratio tests, (5) the Akaike Information Criteria (AIC), and (6) average predicted vs. observed counts. In linear regression models, R^2 represents goodness-of-fit as the percentage of variability in the observation y_i that a model explains. Alternative pseudo-R^2 statistics have been developed for nonlinear and discrete count models (e.g., Cameron and Windmeijer 1996; Fridstrøm et al. 1995; Heinzl and Mittlbock 2003; Miaou 1996). A commonly used one is the pseudo-R^2 based on deviances, $R^2_{dev} = 1 - [D(y,\hat{\mu}) / D(y,\bar{y})]$, where $D(y, \hat{\mu})$ is the deviance statistic for the fit model (twice the difference between the log-likelihood of the fit model and the full model), and $D(y, \bar{y})$ is the deviance statistic for the intercept-only model (a model with $\hat{\mu}_i = \bar{y}$ for all *i*). The R^2_{dev}, which measures the reduction in deviance due to the inclusion of regressors, is always between 0 and 1, and generally increases when new regressors are added, but cannot be used for comparison between Poisson and NB models (Cameron and Windmeijer 1996).

For NB models, the overdispersion parameter, α, can provide information about the goodness-of-fit. If $\alpha = 0$, all the observed variability could be attributed to the randomness one expects from a Poisson distribution. The higher the value of α, the greater the randomness above a Poisson. A smaller α indicates the covariates have better predictive power because the expected difference between y_i and the model's estimate of its mean is smaller (Eq. 5). Therefore, NB models with smaller α values are preferred.

While α itself provides a dimensionless goodness-of fit criterion, it can also be used to compute a pseudo-R^2 statistic, R_α^2, recommended by Miaou (1996). In Eq. 5, the first term, μ_i, is the variance of the Poisson counting process; the second term, $\alpha\mu_i^2$, is the extra unexplained variation due to variability in the true mean $\tilde{\mu}_i$. If the null (intercept-only) model with $\hat{\mu}_i = \bar{y}$ has an alpha parameter of α_0, a reasonable pseudo-R^2 describing the fraction of the total variation in the true means $\tilde{\mu}_i$ (with average value μ) described by a proposed model with parameter α is $R_\alpha^2 = 1-(\alpha/\alpha_0)$, where R_α^2 ranges from 0 to 1. While R_{dev}^2 measures the fraction of the total variation in the raw counts y_i explained by the model, R_α^2 measures the fraction of the total variation in the true Poisson means $\tilde{\mu}_i$ explained by the model. When the mean count μ_i is small (as in this case), most of the variability in the counts y_i can be due to the Poisson variability. As a result, R_{dev}^2 values are much lower than R_α^2.

When comparing nested models (i.e., a pair of models such that one can be represented as a specific case of the other), likelihood ratio tests were used. The likelihood ratio test is a formal hypothesis test in which twice the difference in the log-likelihoods of two models are compared to a chi-squared distribution with degrees of freedom equal to the number of parameters by which the models differ. For nonnested models, the AIC = -2log$L$+2k was useful, where log$L$ is the log-likelihood, k is the number of independent parameters, and the smaller AIC indicates the preferred model (Akaike 1974). Finally, since the models are ultimately intended to be used for prediction of ignitions in future earthquakes, the distribution of predicted total counts from each model $\hat{n}_j$ (i.e., the estimated number of observations with $y_i=j$, j=0, 1, 2,…) were compared to the total observed counts n_j for the dataset (Cameron and Trivedi 1998, p. 156). For each count j, the total predicted counts was calculated as the sum of the probability of that $y_i=j$ over all N observations. For the Poisson, for example, $\hat{n}_j = \sum_{i=1}^{N} \exp(-\hat{\mu}_i)\hat{\mu}_i^j / j!$.

For each dataset, an exhaustive covariate selection process was followed. As discussed in Section 2.3, many of the candidate covariates are highly correlated, and for these purposes can be considered to be essentially alternate measures of the same thing. For example, while there are important differences between PGA, PGV, $S_{a(0.3s)}$, and instrumental intensity all are measures of ground shaking intensity and the correlations among them are 0.84 to 0.92 for Dataset A. The first step, therefore, was to choose the best of the alternate measures, then find the best combination of those and the other covariates, including examination of possible interaction terms. Note that the total building area, *tbldg*, was transformed into $x_{tbldg} = \ln(tbldg)$ before fitting the models.

4.2. Model Selection Results

The analyses of Datasets A and B were similar. This discussion focuses on Dataset A first, then on Dataset B. Table 4-1 summarizes a small selection of the Poisson models fit to Dataset A, Table 4-2 shows the results of selected likelihood ratio tests, and Table 4-3 presents the observed versus predicted distributions of total number of ignitions for different models. Models are referred to as *D.MN*, where *D* is the dataset (A or B), *M* is the model type (Poisson, negative binomial, or mixed model), and *N* is the specific model number. If one compares *A.P1* and *A.P2*,

Table 4-1. Selected Alternative Models of Ignition Counts, Dataset A

	Covariates[b]																				
Model[a]	Int.	x_{ii}	x_{hires}	$x_{\%hires}$	$x_{\%CIT}$	x_{yrblt}	$x_{\%C2L}$	x_{cbldg}	x_{tbldg}	$x_{\%URM}$	x_{dens}	x_{pop}	LP	MH	NPS	NR	WN	R^2_{dev}	AIC	α	R^2_{α}	σ
A.P1	O	X	O	O	X	O	O	O	X	X	X	O						0.29	979	---	---	---
A.P2	X	X			X				X	X	X							0.29	972	---	---	---
A.P3	X	X			X				X	X								0.28	976	---	---	---
A.P4	O	X	X	O	X	O	O	O	X	X	O	O	X	O	X	X	X	0.32	959	---	---	---
A.P5	X	X	X		X				X	X	X		X	O	X	X	X	0.32	953	---	---	---
A.P6	X	X	X		X				X		X		X	O	X	X	X	0.31	956	---	---	---
A.NB1	O	X	O	O	X	O	O	O	X	X	X	O						0.31	974	0.860	0.87	---
A.NB2[c]	X	X			X				X	X	X							0.31	967	0.895	0.86	---
A.NB3	X	X			X				X	X								0.30	970	0.953	0.85	---
A.NB4	O	X	X	O	X	O	O	O	X	O	O	O	O	O	X	X	X	0.34	957	0.585	0.91	---
A.NB5	X	X	X		X				X	X	X		X	O	X	X	X	0.34	950	0.604	0.91	---
A.NB6	X	X	X		X				X		X		O	O	X	X	X	0.33	953	0.686	0.89	---
A.MM1	O	X	X	O	X	O	O	O	X	X	O	O						0.23	706	---	---	0.91
A.MM2	X	X			X				X		X							0.21	706	---	---	0.82
A.MM3	X	X			X				X	X	X							0.22	702	---	---	0.82
A.MM4	X	X			X				X	X								0.21	705	---	---	0.75

Note: An "X" in a cell means the corresponding variable is included in that model, and it is significant to the 0.05 level. An "O" means the corresponding variable is included in the model, but is not significant at the 0.05 level.

[a] In model name *D.MN*, *D* indicates the dataset A or B, *M* indicates the type of model Poisson, negative binomial, or mixed model, and *N* indicates the specific model number.

[b] LP, MH, NPS, NR, and WN are dummy variables representing the Loma Prieta, Morgan Hill, N. Palm Springs, Northridge, and Whittier Narrows earthquake, respectively, with Coalinga being the alternative value for each earthquake. The other covariates are defined in Table 2-1.

[c] Model A.NB2 is the final recommended model for Dataset A.

Table 4-2. Selected Likelihood Ratio Tests for Dataset A

Model comparison[a]	Likelihood ratio test statistic	Degrees of freedom	p-value	Conclusion[b]
A.P1 v. A.P2	5.576	6	0.472	Same
A.P2 v. A.P3	5.589	1	0.018	A.P2 is preferred
A.P4 v. A.P5	3.800	5	0.579	Same
A.P5 v. A.P6	5.111	1	0.024	A.P5 is preferred
A.NB1 v. A.NB2	5.179	6	0.521	Same
A.NB2 v. A.NB3	5.033	1	0.025	A.NB2 is preferred
A.NB4 v. A.NB5	3.439	5	0.633	Same
A.NB5 v. A.NB6	4.200	1	0.040	A.NB5 is preferred
A.MM3 v. A.MM2	6.308	1	0.012	A.MM3 is preferred
A.MM3 v. A.MM4	5.141	1	0.023	A.MM3 is preferred
A.P5 v. A.P2	31.747	6	<0.0001	A.P5 is preferred
A.NB5 v. A.NB2	28.701	6	<0.0001	A.NB5 is preferred
A.P2 v. A.NB2	7.264	1	0.004	A.NB2 is preferred
A.P5 v. A.NB5	4.217	1	0.020	A.NB5 is preferred

[a] The covariates included in each model are indicated in Table 2-2.
[b] Same means there is no statistically significant difference at the 0.05 level

Table 4-3. Predicted vs. Observed Counts for Selected Models with Dataset A

				Number of ignitions							
			Total	0	1	2	3	4	5	6	7
		Observed	148	3,086	110	14	2	1	0	0	0
Poisson	without earthquake	*A.P1*	148.0	3,080	121	10.9	1.5	0.2	0.0	0.0	0.0
		A.P2	148.0	3,080	121	10.7	1.4	0.2	0.0	0.0	0.0
		A.P3	148.0	3,079	121	10.5	1.4	0.2	0.1	0.0	0.0
	With earthquake	*A.P4*	148.0	3,082	117	11.5	1.8	0.4	0.1	0.0	0.0
		A.P5	148.0	3,082	118	11.4	1.8	0.4	0.1	0.0	0.0
		A.P6	148.0	3,081	118	11.4	1.8	0.4	0.1	0.0	0.0
NB	without earthquake	*A.NB1*	148.0	3,086	110	14.5	2.4	0.4	0.1	0.0	0.0
		A.NB2[a]	149.8	3,087	109	13.2	2.9	0.8	0.3	0.1	0.1
		A.NB3	150.0	3,087	108	13.2	2.9	0.9	0.3	0.1	0.1
	With earthquake	*A.NB4*	149.6	3,087	108	13.0	2.9	0.9	0.3	0.1	0.1
		A.NB5	149.6	3,087	109	13.0	2.8	0.9	0.3	0.1	0.1
		A.NB6	150.2	3,088	108	13.1	3.0	1.0	0.4	0.2	0.1
GLMM		*A.MM1*	268.3	2,988	189	25.9	5.8	1.7	0.5	0.2	0.0
		A.MM2	355.5	2,931	229	38.6	9.6	3.0	1.0	0.4	0.1
		A.MM3	355.5	2,931	229	38.6	9.6	3.0	1.0	0.4	0.1
		A.MM4	320.2	2,954	215	33.5	7.9	2.3	0.7	0.2	0.1

[a] Model *A.NB2* is the final recommended model for Dataset A.

for example, the AIC is slightly lower for *A.P2*, the R^2_{dev} are the same, they predict similar distributions of the total number of ignitions (Table 4-3), and a likelihood ratio test comparing the two (Table 4-2) indicates that they are statistically indistinguishable (p-value=0.472), so the simpler model (*A.P2*) is preferred.

Initially, models were fit without including the earthquake indicator covariate (x_{eq}) because its inclusion is problematic when using the models for future prediction. It was hoped that the other more descriptive covariates would capture the important features of the particular earthquakes. To check that that was the case, however, the model selection process was repeated, allowing the earthquake indicator to be included. It turned out to be significant, and the procedure led to *A.P5* being the best Poisson model with earthquake. Based on the AIC and R^2_{dev} values (Table 4-1), a likelihood ratio test comparing them (p-value <0.0001) (Table 4-2), and predicted counts (Table 4-3), the best model with earthquake (*A.P5*) is preferred over the best model without earthquake (*A.P2*). As discussed in Section 4.3, it appears that the significance of the earthquake covariate may be at least partially an artifact of the way ignition data were collected. As a result, and because including the earthquake covariate would hinder application of the models in a predictive mode, the models with the earthquake covariate were not selected. Instead, the issue of missing ignition data is treated by fitting models for Datasets A and B separately, and using both for future application (see Section 6).

While the best Poisson models provide reasonably good fits, comparison to the corresponding NB models suggested evidence of overdispersion, so the exhaustive covariate selection process was repeated using NB models. Again, just a few of the best models are shown in Table 4-1. The best models without and with earthquake included are *A.NB2* and *A.NB5*, respectively. Again, including the earthquake covariate provides the better fit. Likelihood ratio tests indicate that the NB models are preferred over Poisson models (p=0.004 for models without earthquake, p=0.020 for models with earthquake) (Table 4-2). While the estimated total number of ignitions is similar for both Poisson and NB models, and the two include the same covariates, the Poisson overestimates the number of single ignition observations and underestimates the number of zero- and two-ignition observations compared to the NB (Table 4-3).

The significance of the earthquake covariate in the Poisson and NB models suggested fitting GLMMs in which earthquake is treated as a random effect. The best GLMM based on AIC, R^2_{dev}, and likelihood ratio tests (*A.MM3*) includes the same covariates as the best Poisson and NB models without the earthquake covariate (*A.P2* and *A.NB2*) (Table 4-1). The standard deviation of the random effects terms, σ_u, is significantly different from zero, reinforcing the appropriateness of the GLMM. Using a Markov Chain Monte Carlo method implemented in the package *glmfun* (U. Halekoh, unpublished course notes, April 2007, http://genetics.agrsci.dk/statistics/courses/phd07/), a 95% confidence interval for σ_u for *A.MM3* is (0.23, 2.73). However, the predicted ignition counts for the GLMMs are much worse than for the NB models, overestimating the total number of ignitions by more than 100% (Table 4-3).

A similar analysis was conducted using Dataset B. Tables 4-4, 4-5, and 4-6 present a comparison of selected models, likelihood ratio test results, and observed versus predicted distributions of total number of ignitions for different models, respectively, for Dataset B. Based on those results, similar conclusions can be drawn. For both Poisson and NB models, the best model with the earthquake covariate included (*B.P6* and *B.NB6*) is better than the best model without the earthquake covariate included (*B.P4* and *B.NB2*). Both the likelihood ratio test comparing *B.P6* and *B.P4* and the one comparing *B.NB6* and *B.NB3* both have p-values <0.0001 (Table 4-5). While *B.NB6* and *B.NB2* could not be compared directly because they are not nested models, the *B.NB6* versus *B.NB3* test suggests a similar conclusion. The analysis of Dataset B also similarly leads to a conclusion that, with or without the earthquake covariate, the negative

Table 4-4. Selected Alternative Models of Ignition Counts for Dataset B

	Covariates[b]																				
Model[a]	Int.	x_{ii}	x_{hires}	$x_{\%hires}$	$x_{\%CIT}$	x_{yrblt}	$x_{\%C2L}$	x_{cbldg}	x_{tbldg}	$x_{\%URM}$	x_{dens}	x_{pop}	LP	MH	NPS	NR	WN	R^2_{dev}	AIC	α	R^2_{α}	σ
B.P1	X	X	X	O	X	X	O	O	O	X	X	O						0.31	1143	---	---	---
B.P2	X	X	X		X	X				X	X							0.30	1143	---	---	---
B.P3	X	X			X	X			X	X	X							0.30	1144	---	---	---
B.P4	X	X	X		X	X			X	X	X							0.31	1141	---	---	---
B.P5	X	X	O	O	X	O	O	X	O	X	X	O	X	O	O	X	X	0.33	1129	---	---	---
B.P6	X	X	O		X	X			X	X	X		X	O	O	X	X	0.33	1123			
B.P7	X	X			X	X			X	X	X		X	X	O	X	X	0.33	1123			
B.P8	X	X	X		X	X				X	X		X	O	O	X	X	0.32	1128	---	---	---
B.NB1	X	X	O	O	X	X	O	O	O	X	X	O						0.35	1129	1.931	0.89	---
B.NB2[c]	X	X	X		X	X				X	X							0.34	1128	1.965	0.89	---
B.NB3	X	X			X	X				X	X							0.34	1132	2.151	0.88	---
B.NB4	X	X			X	X				X								0.33	1138	2.481	0.86	---
B.NB5	X	X	O	O	X	X	O	O	O	X	X	O	X	O	O	X	O	0.37	1118	1.555	0.91	---
B.NB6	X	X			X	X			X	X	X		X	O	O	X	O	0.36	1111	1.631	0.91	---
B.NB7	X	X			X	X				X	X		X	O	O	X	O	0.36	1119	1.742	0.90	---
B.NB8	X	X			X	X				X			X	O	O	X	O	0.35	1126	2.000	0.89	---
B.MM1	X	X	X	O	X	X	O	O	O	X	X	O						0.88	872	---	---	0.55
B.MM2	X	X	X		X	X			X	X	X							0.88	866	---	---	0.58
B.MM3	X	X			X	X			X	X	X							0.87	867	---	---	0.65
B.MM4	X	X			X	X				X	X							0.87	876	---	---	0.55
B.MM5	X	X	X		X	X				X	X							0.87	871	---	---	0.53

Note: An “X” in a cell means the corresponding variable is included in that model, and it is significant to the 0.05 level. An “O” means the corresponding variable is included in the model, but is not significant at the 0.05 level.

[a] In model name *D.MN*, *D* indicates the dataset A or B, *M* indicates the type of model Poisson, negative binomial, or mixed model, and *N* indicates the specific model number.

[b] LP, MH, NPS, NR, and WN are dummy variables representing the Loma Prieta, Morgan Hill, N. Palm Springs, Northridge, and Whittier Narrows earthquake, respectively, with Coalinga being the alternative value for each earthquake. The other covariates are are defined in Table 2-1.

[c] Model *B.NB2* is the final recommended model for Dataset B.

Table 4-5. Selected Likelihood Ratio Tests for Dataset B

Model comparison[a]	Likelihood ratio test statistic	Degrees of freedom	p-value	Conclusion[b]
B.P1 v. B.P2	9.407	5	0.094	Same
B.P4 v. B.P2	4.039	1	0.044	B.P4 is preferred
B.P4 v. B.P3	5.831	1	0.016	B.P4 is preferred
B.P5 v. B.P6	1.425	4	0.840	Same
B.P7 v. B.P6	2.665	1	0.103	Same
B.P8 v. B.P6	7.886	1	0.005	B.P6 is preferred
B.NB1 v. B.NB2	8.942	5	0.111	Same
B.NB3 v. B.NB2	6.756	1	0.009	B.NB2 is preferred
B.NB4 v. B.NB2	13.91	2	0.001	B.NB2 is preferred
B.NB2 v. B.NB3	6.756	1	0.009	B.NB2 is preferred
B.NB5 v. B.NB6	3.315	5	0.652	Same
B.NB6 v. B.NB7	9.588	1	0.002	B.NB6 is preferred
B.NB7 v. B.NB8	9.516	1	0.002	B.NB7 is preferred
B.NB6 v. B.NB8	19.104	2	<0.0001	B.NB6 is preferred
B.MM1 v. B.MM2	1.8821	4	0.757	Same
B.MM2 v. B.MM3	3.117	1	0.077	Same
B.MM2 v. B.MM5	6.9785	1	0.008	B.MM2 is preferred
B.MM3 v. B.MM4	10.4744	1	0.001	B.MM3 is preferred
B.P6 v. B.P4	27.965	5	<0.0001	B.P6 is preferred
B.NB6 v. B.NB3	33.301	6	<0.0001	B.NB6 is preferred
B.P2 v. B.NB2	17.026	1	<0.0001	B.NB2 is preferred
B.P7 v. B.NB6	14.232	1	<0.0001	B.NB6 is preferred

[a] The covariates included in each model are indicated in Table 2-2.
[b] Same means there is no statistically significant difference at the 0.05 level

Table 4-6. Predicted vs. Observed Counts for Selected Models with Dataset B

			Number of ignitions								
			Total	0	1	2	3	4	5	6	7
		Observed	148	7,793	110	14	2	1	0	0	0
Poisson	without earthquake	*B.P1*	148.0	7,782	129	7.8	0.8	0.1	0.0	0.0	0.0
		B.P2	148.0	7,781	130	7.5	0.7	0.1	0.0	0.0	0.0
		B.P3	148.0	7,781	130	7.5	0.7	0.1	0.0	0.0	0.0
		B.P4	148.0	7,782	130	7.7	0.8	0.1	0.0	0.0	0.0
	with earthquake	*B.P5*	148.0	7,784	126	8.7	1.2	0.2	0.0	0.0	0.0
		B.P6	148.0	7,784	126	8.6	1.2	0.2	0.0	0.0	0.0
		B.P7	148.0	7,784	126	8.6	1.2	0.2	0.0	0.0	0.0
		B.P8	148.0	7,783	127	8.3	1.1	0.2	0.0	0.0	0.0
NB	without earthquake	*B.NB1*	149.0	7,793	111	11.9	2.6	0.8	0.3	0.1	0.1
		B.NB2[a]	148.0	7,793	112	11.8	2.4	0.7	0.3	0.1	0.1
		B.NB3	148.3	7,793	112	12.0	2.5	0.7	0.3	0.1	0.0
		B.NB4	149.6	7,791	110	12.4	2.7	0.8	0.3	0.1	0.1
	with earthquake	*B.NB5*	150.1	7,793	110	11.7	2.8	1.0	0.4	0.2	0.1
		B.NB6	150.3	7,793	110	11.8	2.8	1.0	0.4	0.2	0.1
		B.NB7	149.7	7,793	111	11.8	2.7	0.9	0.4	0.2	0.1
		B.NB8	150.6	7,792	110	12.0	2.8	1.0	0.4	0.2	0.1
GLMM		*B.MM1*	285.1	7,676	212	24.3	4.9	1.4	0.5	0.2	0.1
		B.MM2	306.9	7,661	224	27.0	5.8	1.7	0.6	0.2	0.1
		B.MM3	346.6	7,632	245	32.2	7.1	2.2	0.8	0.3	0.1
		B.MM4	286.0	7,671	219	23.9	4.2	1.0	0.3	0.1	0.0
		B.MM5	272.4	7,683	208	22.5	4.1	1.0	0.3	0.1	0.0

[a] Model *B.NB2* is the final recommended model for Dataset B.

binomial models are preferred over Poisson models. As Table 4-5 shows, the likelihood ratio tests of *B.P2* versus *B.NB2* (without the earthquake covariate) and *B.P7* versus *B.NB6* (with the earthquake covariate) both have p-values <0.0001. Again, while the estimated total number of ignitions is similar for both Poisson and NB models, the Poisson models overestimate the number of single ignition observations and underestimate the number of zero- and two-ignition observations compared to the NB models (Table 4-6). Finally, for Dataset B, the GLMMs again substantially overestimate the number of ignitions compared to the NB and Poisson models (Table 4-6).

4.3. Earthquake Effect

There are many possible reasons the earthquake covariate (x_{eq}) was significant in the Poisson and NB models. It could be capturing characteristics of the specific earthquakes or regions they affected that were not captured by the other covariates. It appears, however, that the significance of the earthquake covariate may be at least partially an artifact of how the ignition data were collected.

For Dataset A, the parameter estimates indicate that the models with the earthquake covariate predict more ignitions (higher μ) for observations associated with the Coalinga and Morgan Hill earthquakes, and to a lesser extent Loma Prieta. For Model *A.NB5*, for example, with Coalinga as the zero value for all dummy variables, $\hat{\beta}_{LP} = -1.735$, $\hat{\beta}_{MH} = -0.171$, $\hat{\beta}_{NPS} = -3.190$, $\hat{\beta}_{NR} = -2.471$, and $\hat{\beta}_{WN} = -2.352$. Recall that Dataset A only includes those census tracts that experienced a nonzero PGA and that are in a jurisdiction for which ignition data were available. The percentage of missing tracts (i.e., those that experienced nonzero PGA but are in a jurisdiction for which ignition data were *not* available) is different for each earthquake. It is reasonable to assume that the missing tracts are more likely to be zero counts than the included tracts; otherwise data would more likely have been collected for them. If that is true, then Coalinga, Morgan Hill, and to a lesser extent, Loma Prieta are missing more zero counts than the other earthquakes (Table 4-7), which could help explain why the models want to estimate higher ignition counts for them.

For Dataset B, the parameter estimates indicate that the models with the earthquake covariate predict fewer ignitions (lower μ) for observations associated with Loma Prieta and to a lesser extent Northridge. For Model *B.NB6*, for example, with Coalinga as the zero value for all dummy variables, $\hat{\beta}_{LP} = -2.742$, $\hat{\beta}_{MH} = -1.246$, $\hat{\beta}_{NPS} = -1.203$, $\hat{\beta}_{NR} = -2.004$, and

$\hat{\beta}_{WN} = -1.158$. Dataset B assumes zero counts for tracts that experienced nonzero PGA but are not in jurisdictions where data were collected. It is reasonable to assume that those tracts are more likely to contain unrecorded ignitions if they experienced substantial ground shaking. If that is true, then Loma Prieta, which had many missing observations that experienced substantial ground shaking (Table 4-7), may be missing more ignition counts than the other earthquakes, which could help explain why the models want to estimate lower counts for it. The same is true to a lesser extent for Northridge. This analysis highlights the importance of more comprehensive ignition data collection in the future, and shows how the use of the two datasets in this study aims to obtain the best insights possible given the limitations of the currently available data.

Table 4-7. Missing Observations by Earthquake

Earthquake	Coalinga	Loma Prieta	Morgan Hill	N. Palm Springs	Northridge	Whittier Narrows
Num. (%) missing observations*	413 (99%)	866 (75%)	1,461 (99%)	91 (54%)	1,247 (51%)	627 (28%)
Num. of observations with PGA>0	416	1,149	1,481	167	2,462	2,243
Average instrumental intensity of missing tracts	4.55	7.15	4.94	5.58	6.08	5.23

* "Missing" observations are those that experienced nonzero PGA, but are in a jurisdiction for which ignition data were *not* available.

SECTION 5

RECOMMENDED MODELS

5.1. Goodness-of-fit and Model Diagnostics

Based on the analyses above, models *A.NB2* and *B.NB2* are recommended for Datasets A and B, respectively. The parameter estimates for both models are in Table 5-1, and the goodness-of-fit metrics are in Tables 4-1 and 4-4. The performance of the models was examined to detect possible model misspecification and any observations with particularly poor fit or large influence. The R^2_{dev} and R^2_{α} provide overall measures of the models' goodness-of-fit. As expected, the R^2_{dev} values are relatively low, at 0.31 and 0.34, for the best models for Dataset A and B, respectively, indicating that most of the variability in the counts is still not captured by the models. The *A.NB2* and *B.NB2* R^2_{α} values of 0.86 and 0.89, respectively, however, suggest that the best models do capture most of the extra-Poisson variability. Most of the randomness in the ignition counts is due to inherent Poisson randomness, which cannot be reduced, not uncertainty in the means, which in principle could be reduced with better data and models.

Table 5-1. Parameter Estimates for Final Recommended Models for Datasets A and B

	Model *A.NB2*				Model *B.NB2*			
Covariate	Estimate	Std. Error	z	p-value	Estimate	Std. Error	z	p-value
(Intercept)	-15.42	1.42	-10.84	< 2e-16	39.35	16.41	2.40	1.65E-02
x_{ii}	1.13	0.08	13.61	< 2e-16	1.33	0.09	14.36	< 2e-16
$x_{\%hires}$	---	---	---	---	1.58E-06	5.19E-07	3.04	2.37E-03
$x_{\%CIT}$	-32.48	7.30	-4.45	8.52E-06	-25.07	6.80	-3.69	2.26E-04
x_{tbldg}	0.85	0.22	3.88	1.03E-04	---	---	---	---
x_{yrblt}	---	---	---	---	-2.70E-02	8.42E-03	-3.21	1.34E-03
$x_{\%URM}$	27.72	10.64	2.60	9.21E-03	45.54	9.88	4.61	4.07E-06
x_{dens}	4.53E-05	1.94E-05	2.34	1.95E-02	6.33E-05	1.87E-05	3.39	7.04E-04
$\theta=1/\alpha$	1.117	0.557			0.509	0.195		

Note: Variables are defined in Table 2-1.

In terms of their usefulness as predictive models, recognizing that the models were fit to this data, the predicted counts in Tables 4-3 and 4-6 suggest that *A.NB2* and *B.NB2* estimate the distribution of counts for the entire region well. It is difficult to assess the models' abilities to correctly capture the relative ignition rates across census tracts within the region because of the large inherent randomness in the ignition process and the limited historical data available. Nevertheless, models can be compared to see if they estimate similar ignition rates for each observation *i* (creating similar geographic patterns of ignition rate). Plotting the mean ignition rates $\hat{\mu}_i$ estimated by models *A.NB5* and *A.NB2*, the best with and without earthquake, respectively (Figure 5-1a), for example, shows that most estimates are similar, except a few associated with the Coalinga and Morgan Hill earthquakes, for which *A.NB5* estimates higher ignition rates. Without the six points in the upper left corner, $\rho = 0.96$; with them, $\rho = 0.86$. Figure 1b, which similarly compares the two recommended models, *A.NB2* and *B.NB2*, indicates that the geographic pattern is similar ($\rho = 0.85$), but not exactly the same for the Dataset A and B models. Comparing Poisson vs. NB models with the same covariates shows highly correlated estimates ($\rho \geq 0.95$). Comparing GLMMs to similar Poisson or NB models without the earthquake covariate shows high correlations ($\rho \approx 0.95$), but the GLMMs consistently estimate ignition rates about twice as high.

In classical linear regression with normal errors, one expects residuals to have a mean of zero, constant variance, and a symmetric distribution. For count data, however, raw residuals have a discrete asymmetric distribution with a variance that depends on the mean (Eqs. 3 and 5). One of several residuals developed to overcome these problems is the deviance residual, $d_i = sign(y_i - \hat{\mu}_i)\sqrt{2\{l(y_i) - l(\hat{\mu}_i)\}}$, where $l(y)$ and $l(\hat{\mu})$ are the log-density of *y* evaluated at $\mu = y$ and $\mu = \hat{\mu}$, respectively (Cameron and Trivedi 1998, p.141-142). The sum of the squares

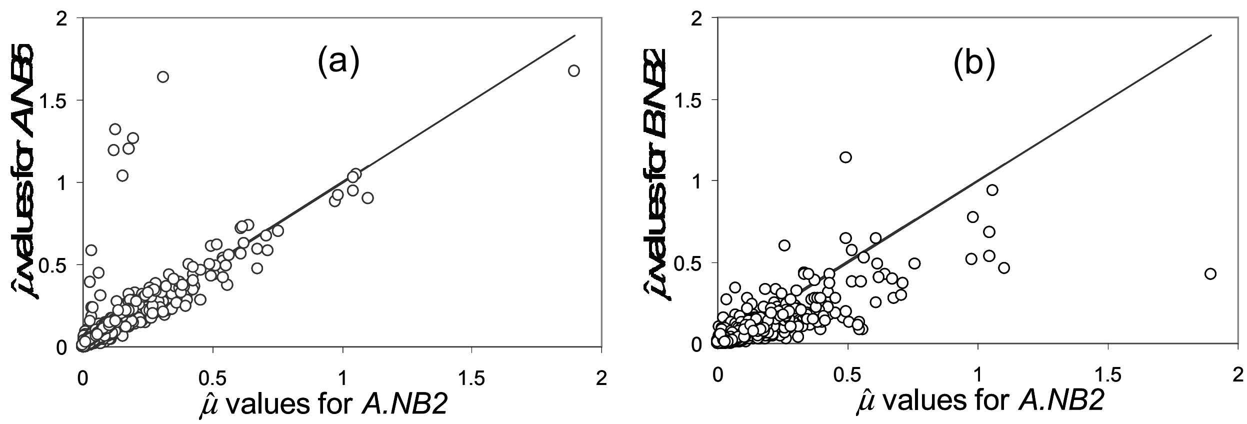

Figure 5-1. Comparison of mean ignition rates $\hat{\mu}_i$ as estimated by Models (a) *A.NB5* vs. *A.NB2*, and (b) *B.NB2* vs. *A.NB2*. Note that for Model *B.NB2*, only those observations that Datasets A and B have in common are plotted.

of the deviance residuals is the deviance statistic *D* in the R^2_{dev} definition. Deviance residuals should have roughly a zero mean and unit variance, and are useful for identifying unusual observations. Figures 5-2 and 5-3 show plots of deviance residuals versus selected important covariates, for the final models for Datasets A and B (*A.NB2* and *B.NB2*). Figures 4a and 4b show plots of deviance residuals versus linear predictors for *A.NB2* and *B.NB2*, respectively. These plots were examined for a possible undesirable nonlinear relationship and or nonconstant variance. However, as is common for Poisson and NB models will small responses, Figures 5-4a and 4b show curved lines of points corresponding to the observed responses, making it difficult to see patterns. After correcting for discreteness as recommended by Pierce and Schafer (1986), normal scores plots show the deviance residuals for *A.NB2* and *B.NB2* are roughly normal (Figure 5-5a and 5-5b). Note that because of the correction, however, the mean is no longer zero. None of these figures suggest any serious problems.

The leverage of a particular observation, given by the associated diagonal entry of the hat matrix, represents the potential of the observation to influence the fit of the model (Faraway

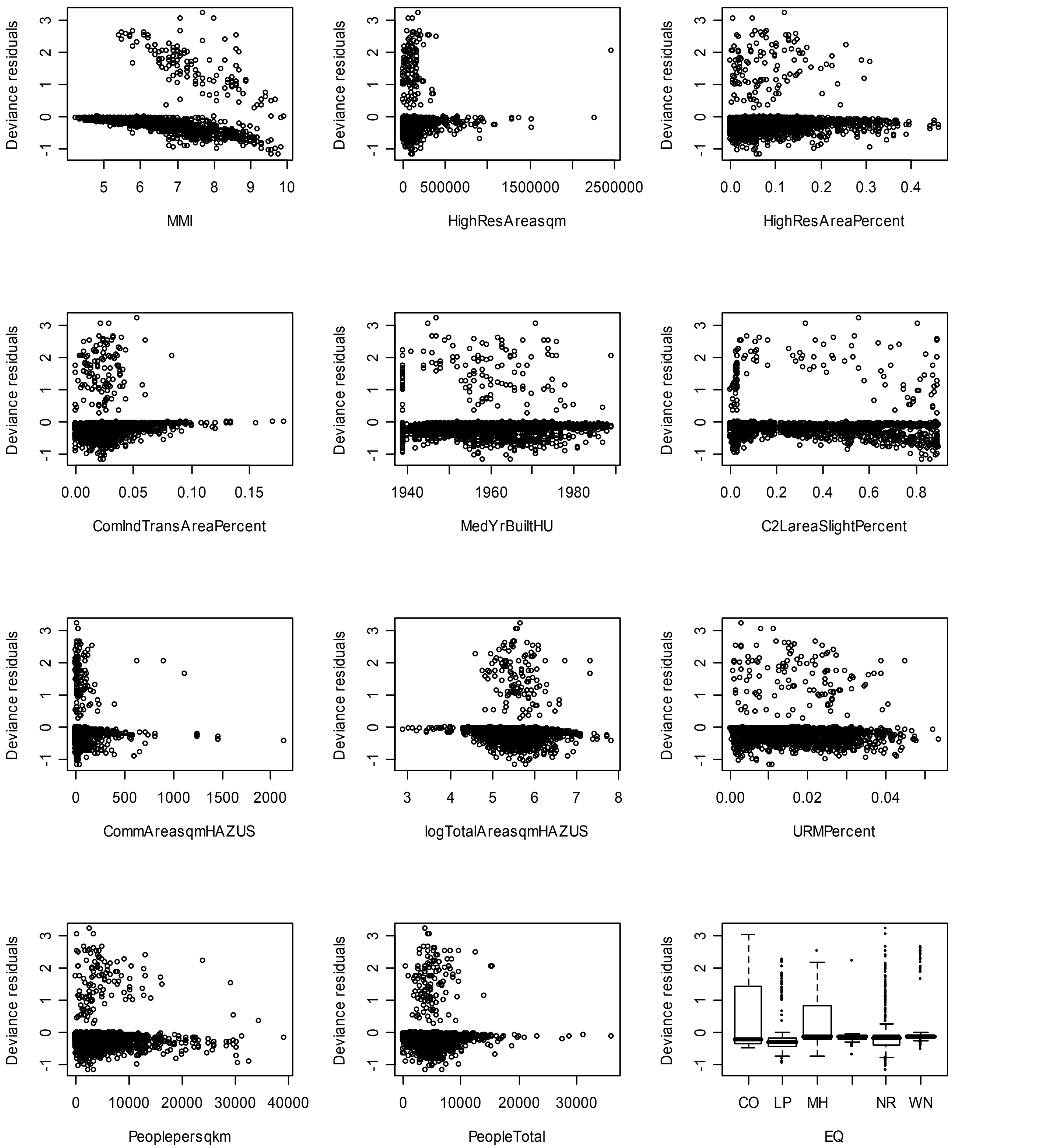

Figure 5-2. Deviance residuals vs. selected covariates for model *A.NB2*

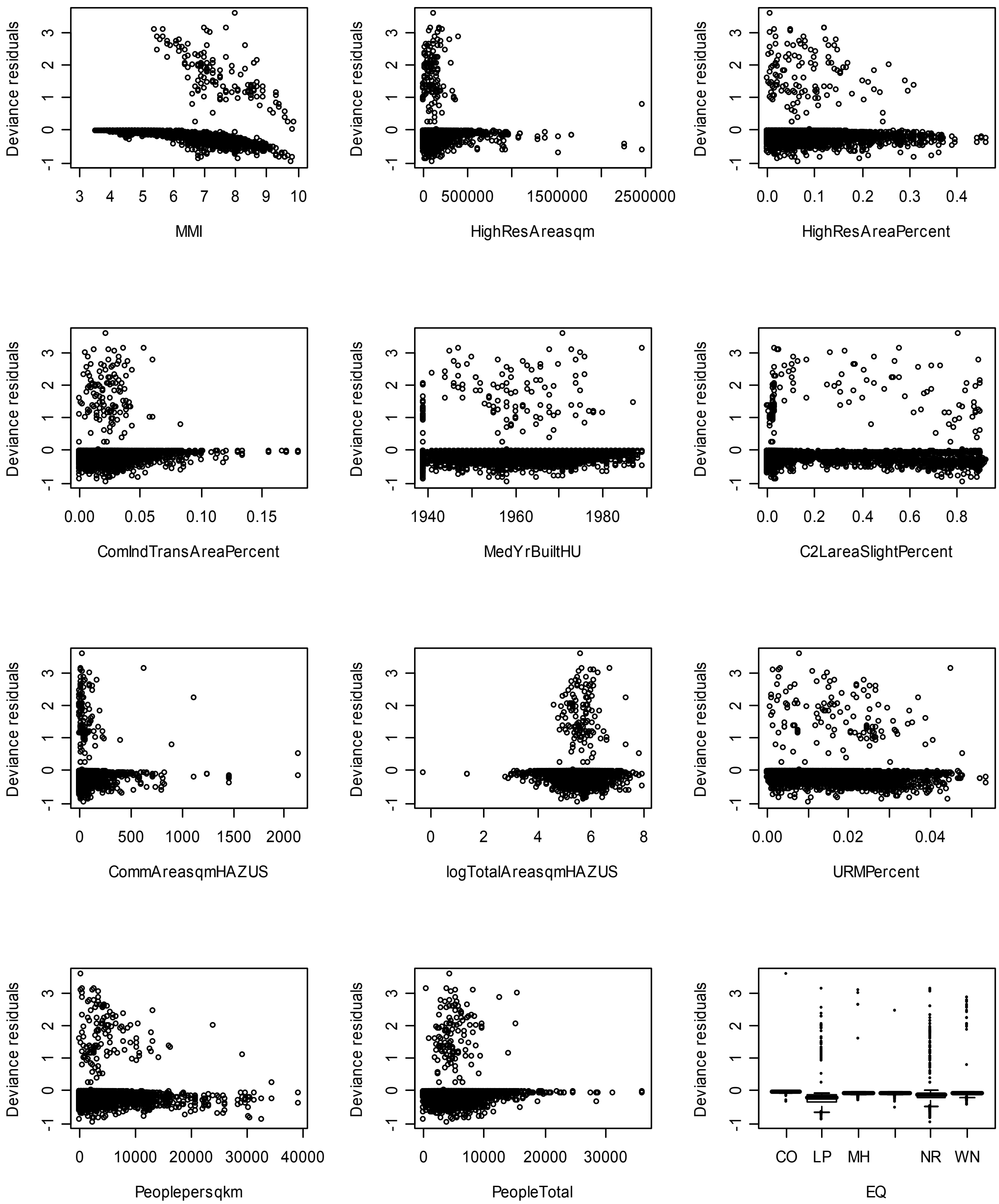

Figure 5-3. Deviance residuals vs. selected covariates for model *B.NB2*

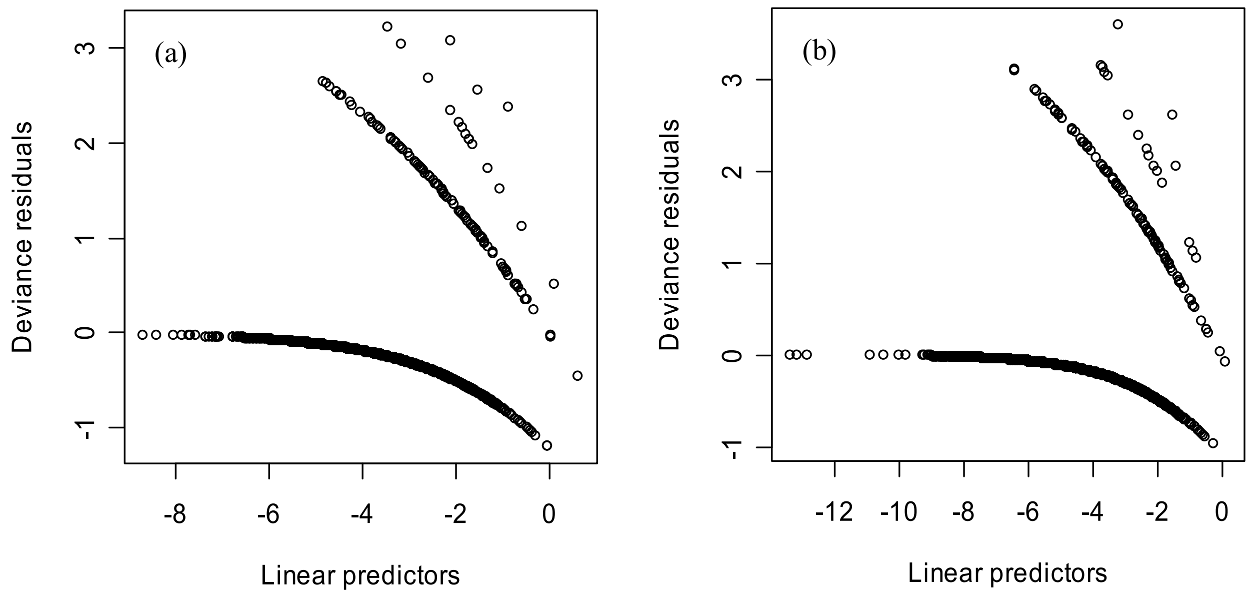

Figure 5-4. Deviance residuals vs. linear predictors for models (a) *A.NB2* and (b) *B.NB2*

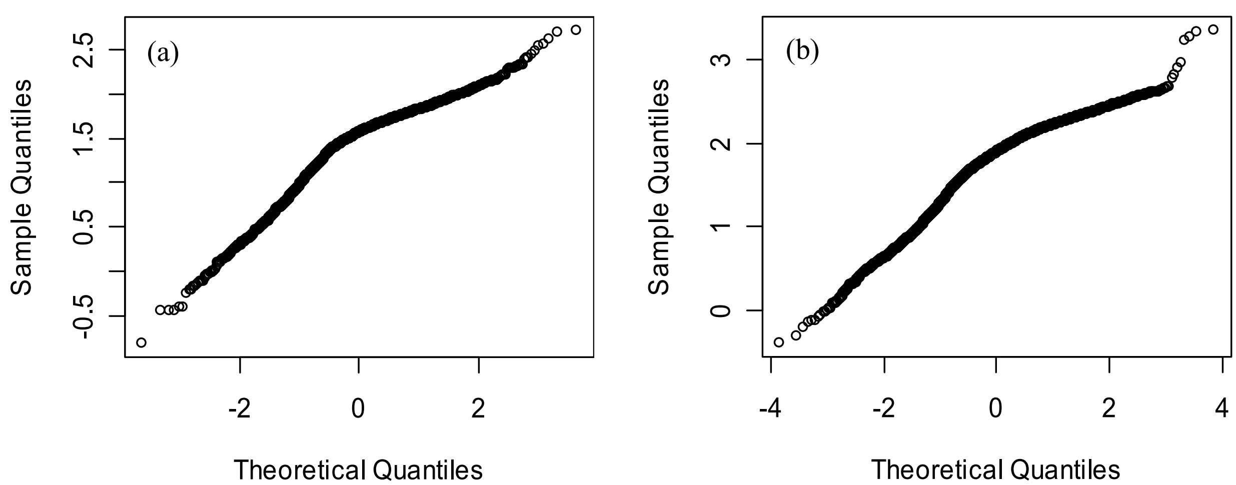

Figure 5-5. Normal scores plots of deviance residuals for models (a) *A.NB2* and (b) *B.NB2*

2006). A large leverage value typically indicates that the covariate values are unusual in some way. Figures 5-6 and 5-7 show index plots and half-normal plots, respectively, of the leverages for the final models *A.NB2* and *B.NB2*. They identify a few observations with particularly high leverage values in each case. For *A.NB2*, the five highest leverages are associated with observations from San Francisco in the Loma Prieta earthquake. The one with the highest value (3129) has the largest value of total building area (x_{tbldg}=2,459 sq m) and a high percentage of unreinforced masonry buildings ($x_{\%URM}$ = 4.8%). The next three highest values have unusually high population densities (x_{dens} > 29,500 people per sq km). For *B.NB2*, the five highest leverages are associated with observations from Los Angeles. They have unusually high values of percentage of land area that is commercial, industrial, or transportation ($x_{\%CIT}$=8.4%, 8.4%, 8.6%, 5.5%, 8.6%) and high percentages of unreinforced masonry buildings ($x_{\%URM}$ = 3.9%, 3.9%, 2.1%, 3.9%, 2.1%). None of these results suggested a need to modify any data.

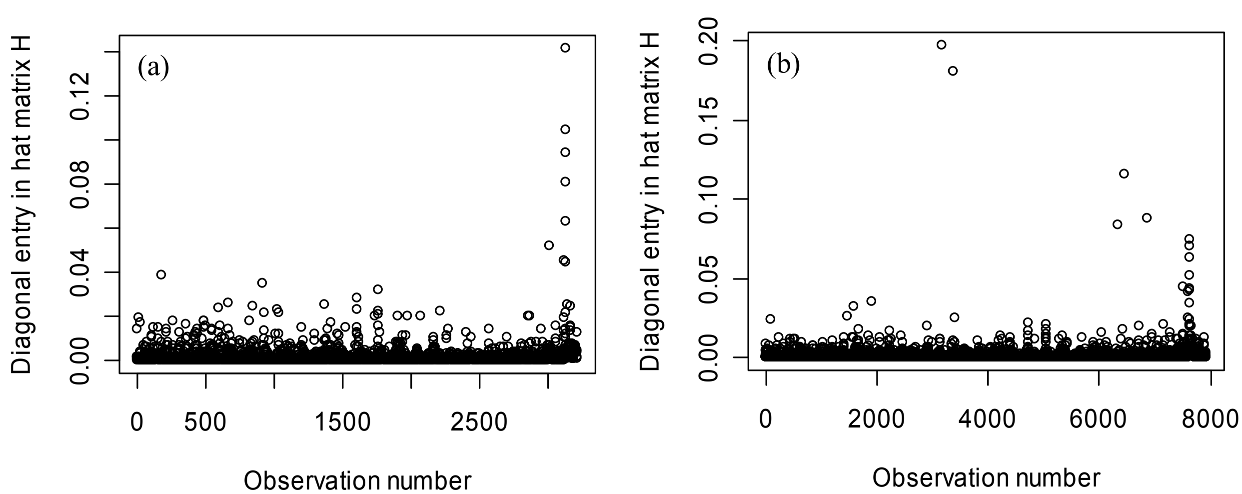

Figure 5-6. Index plots of leverages for models (a) *A.NB2* and (b) *B.NB2*

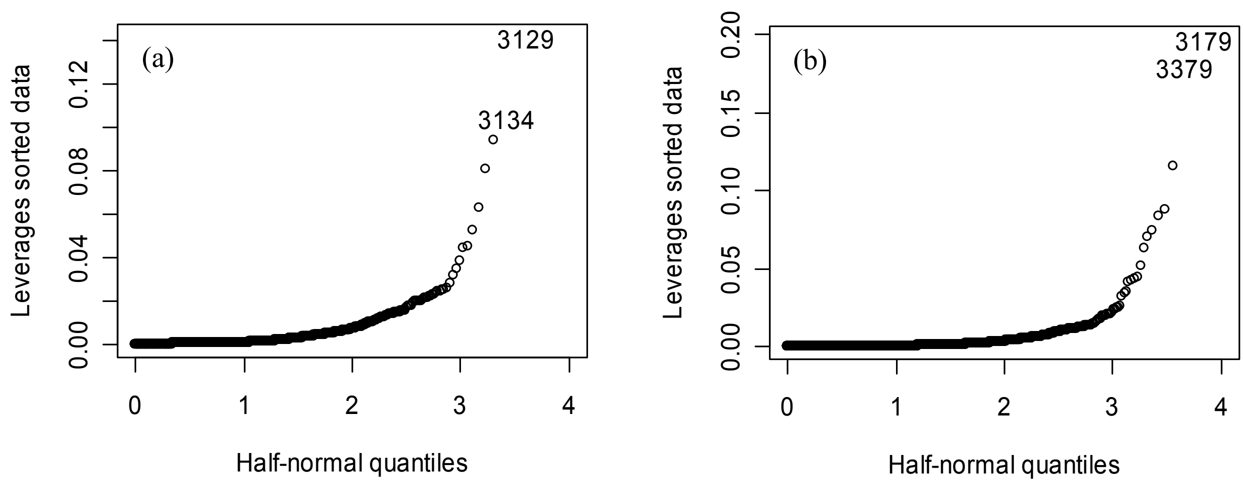

Figure 5-7. Half-normal plots of leverages for models (a) *A.NB2* and (b) *B.NB2*

Finally, while leverage represents the potential to affect fit, cooks statistics can be used to assess the actual effect of each observation on the model fit. Specifically, they measure, for each observation, the change in the coefficients caused by omitting the observation (Faraway 2006). Figure 5-8a and 5-8b present half-normal plots of the cooks statistics for models *A.NB2* and *B.NB2*, respectively. In *A.NB2*, the two most influential observations have TWO ignitions. The highest (2716) also has a relatively high value for $x_{\%CIT}$ (5.3%), and the second highest (3124) has a relatively high value for x_{dens} (23,866). In *B.NB2*, the most influential observation (3) is also associated with 2 ignitions. It also has the highest value of median year built (x_{yrblt}=1989) and a relatively high value of $x_{\%URM}$ (4.5%). This analysis highlights the importance of the few observations with more than one ignition in fitting the models. Care should be taken to ensure multiple counts are correct.

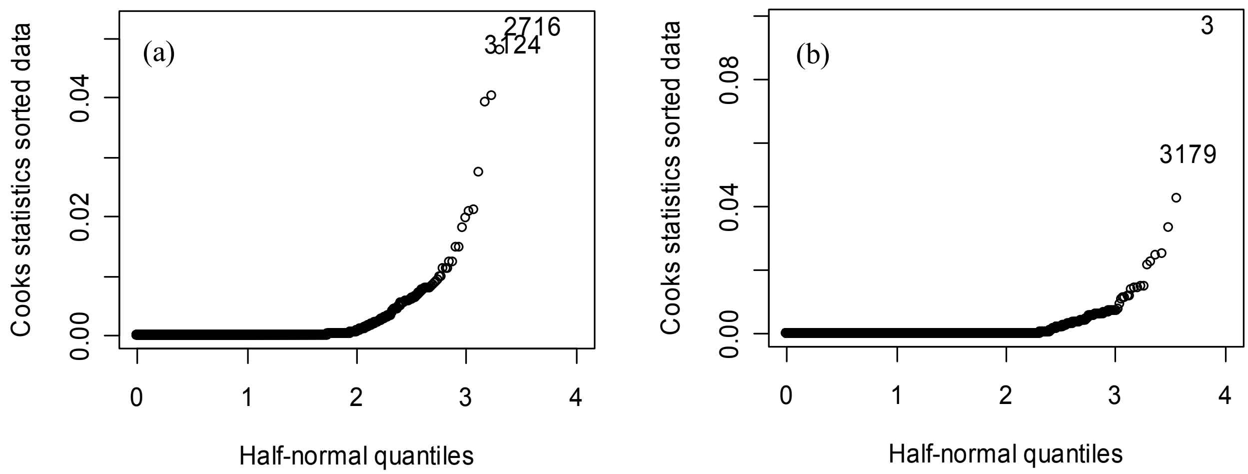

Figure 5-8. Half-normal plots of cooks statistics for models (a) *A.NB2* and (b) *B.NB2*

5.2. Covariates

For Dataset A, the covariates included in the final model are instrumental intensity (x_{ii}), percentage of land area that is commercial, industrial, or transportation ($x_{\%CIT}$), ln(total building area) (x_{tbldg}), percentage of building area that is unreinforced masonry, URM ($x_{\%URM}$), and people per sq. km. (x_{dens}). As expected, more severe ground shaking, more building area, and denser population are associated with more ignitions. Less obviously, the covariate $x_{\%CIT}$ was highly significant and negative in all models. It ensures that tracts that are mostly commercial, industrial, or transportation will have few ignitions. Since the URM covariate, $x_{\%URM,}$ is highly negatively correlated ($\rho \approx -0.85$) with wood buildings and highly positively correlated ($\rho \approx 0.85$) with the percentages of the other building types, it may be an indicator of which building types are present in a particular tract. URMs are also particularly vulnerable to earthquake ground shaking, so $x_{\%URM}$ could be an indicator of building damage. Although there were other direct measures of damage (Table 2-1, variables 27 to 32), they were estimated using the HAZUS-MH MR2 model with default data not based on observations, so the data may not have been accurate enough for those covariates to be significant.

For Dataset B, the same covariates are significant with the same signs and roughly the same magnitudes, with a couple exceptions. First, in the final Dataset B model, *B.NB2*, area of high-intensity residential development (x_{hires}) is significant instead of ln(total building area) (x_{tbldg}). Both seem to capture the idea that the amount of development in a tract is important. The x_{hires} refers to just residential development, where a large percentage of post-earthquake fires occur (Scawthorn et al. 2005) and is a measure of land use, whereas x_{tbldg} refers to all occupancy types and is a measure of building area. Second, in the Dataset B model, median year built over all housing units (x_{yrblt}) is significant and negative, suggesting that older buildings are associated with more ignitions. However, x_{yrblt} could partially be an indicator of San Francisco County, which has by far the lowest x_{yrblt} value—1945 vs. 1956 for the next lowest county and an average of 1963 for all other counties (Figure 5-9).

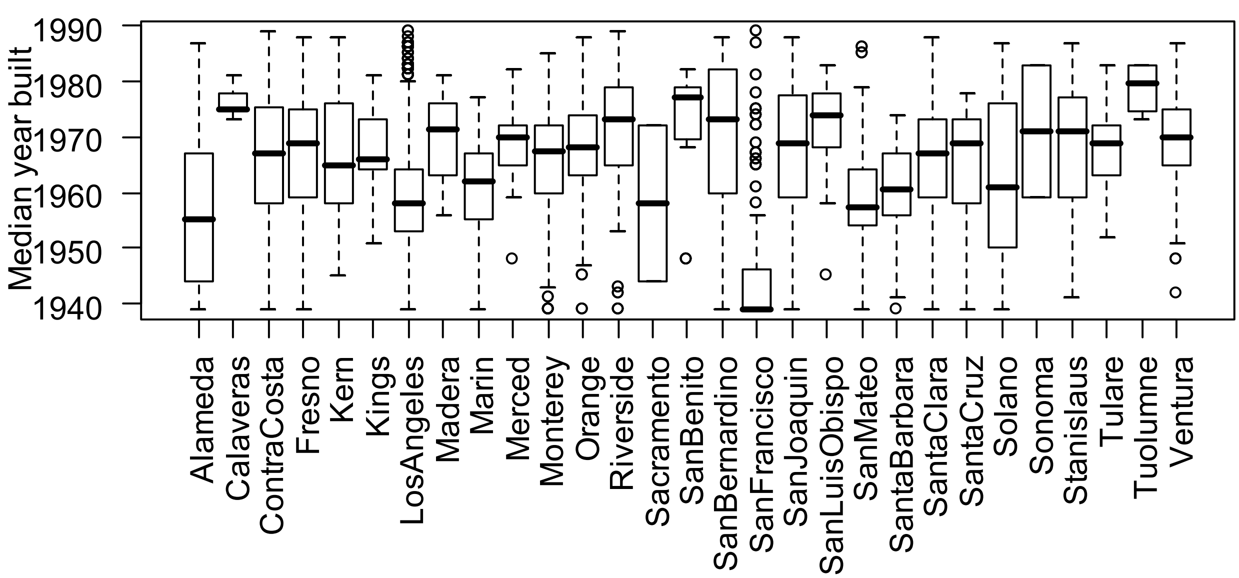

Figure 5-9. Median year built (x_{yrblt}) vs. county for Dataset B

The relative importance of the covariates and the effect of each on the expected number of ignitions can be evaluated using the relative rate of change in μ_i for a unit change in covariate *a* (Cameron and Trivedi 1998):

$$\delta_a = \frac{1}{\mu(\bar{x}_i)}\frac{\partial\mu(\bar{x}_i)}{\partial x_a} = \frac{1}{\mu(\bar{x}_i)}\left[\beta_a \exp(\bar{x}_i^T\vec{\beta})\right] = \frac{\beta_a\mu(\bar{x}_i)}{\mu(\bar{x}_i)} = \beta_a \tag{7}$$

Since total building area x_{tbldg} is natural log-transformed, in that case $\delta_{tbldg} = \beta_{tbldg}/tbldg_i$. The relative effect of changes in total building area depends on how much building area is in a tract. To compare with the other covariates, δ_{tbldg} is evaluated at $tbldg_i = E[tbldg]$. Because the units and variability differ for each covariate, x_a, a unit change does not mean the same thing for all of them, and it is helpful to also consider the relative effect from a change proportional to the standard deviation, σ_a, which yields: $\delta_{\sigma a} = \beta_a\sigma_a$ (Cameron and Trivedi 1998).

The δ_a values (i.e., the covariate estimates in Table 2-4) show that in model *A.NB2*, for example, an increase of one unit in instrumental intensity results in a 113% increase in the expected number of ignitions $\hat{\mu}$ (Figure 5-10). Figure 5-11, which compares the values of $\delta_{\sigma a}$ for the two final models, indicates for example, that in *A.NB2* a one-standard-deviation increase in people per sq. km. leads to an 18% increase in $\hat{\mu}$. Based on $\delta_{\sigma a}$, in both models, the instrumental intensity (x_{ii}) is the most influential covariate, followed by percentage of land area that is commercial, industrial, or transportation ($x_{\%CIT}$).

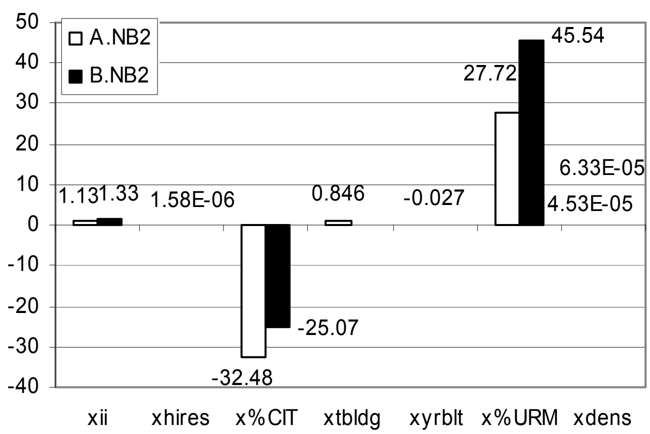

Figure 5-10. Relative effects (δ_a) of covariates *a* in final recommended Dataset A and B models

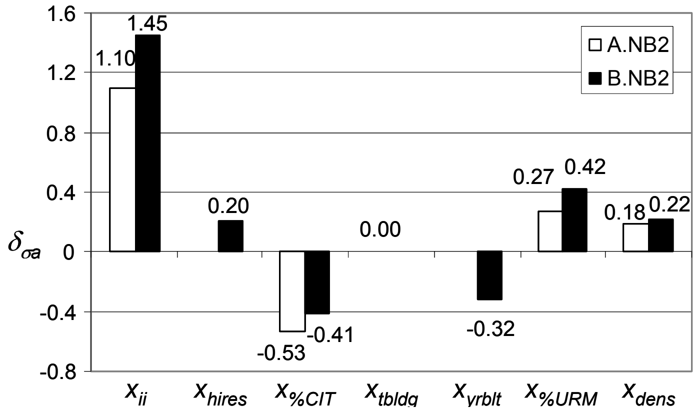

Figure 5-11. Relative effects ($\delta_{\sigma a}$) of covariates *a* in final recommended Dataset A and B models

SECTION 6

MODEL APPLICATION

The *A.NB2* and *B.NB2* models are the best fits to two different datasets, neither of which perfectly captures the "true" pattern of occurrence of historical post-earthquake ignitions. In general, *A.NB2* estimates more ignitions than *B.NB2* (the mean value of $\hat{\mu}_i$ over all observations is 0.045 for *A.NB2* and 0.019 for *B.NB2*, Tables 2-1 and 2-2). *A.NB2* probably estimates too many ignitions (although some ignitions are probably missing from Dataset A too); *B.NB2* probably estimates too few.

Thus, the best way to predict ignitions for a future or hypothetical earthquake is to apply both models and compare the results. Specifically, one would use *A.NB2* (Eq. 2 and Table 5-1) to estimate $\hat{\mu}_i$ for each census tract *i* in the study area. One would then simulate many realizations of the distribution of ignitions throughout the study area using the NB distribution (Eq. 4) with the $\hat{\mu}_i$ values and $\alpha = 0.895$ (Table 4-1). The process would be repeated for model *B.NB2* using common random numbers for the two model applications to avoid introducing additional sampling randomness. The ignitions simulated from each model could then be used to obtain fire spread, economic loss, or other quantities. Hopefully, the results from the two models would be similar enough to lead to similar policy recommendations. If not, the model results should still give rough bounds on what can be expected, but unfortunately, the user would have to accept the indeterminacy in the ignition data as a limit on what conclusions could be drawn.

SECTION 7

CONCLUSIONS

This report presents a comprehensive approach to statistical modeling of post-earthquake ignitions and data compilation for such modeling, and applies it to present day California. Several important issues involved in compiling a post-earthquake ignition dataset are highlighted, including the need to explicitly and consistently define which ignitions are considered, which area units data are collected for, and what the unit of study is. These decisions influence the conclusions that can be drawn from subsequent statistical analysis, as demonstrated by the effect of the missing ignition data in this analysis. Following future earthquakes, researchers should strive to obtain ignition counts for all areas that experience ground shaking, and therefore, may have experienced earthquake-related ignitions.

The statistical modeling approach introduced offers some advantages over previous efforts. Using GLMs and GLMMs in this application for the first time provides a more natural treatment of discrete, nonzero ignition counts. Unlike previous models that focus on a single predictor, many covariates were examined, and several were ultimately identified as significant. Using census tracts as the unit of study also allows simulation for future earthquakes to produce estimates at a finer geographic resolution. Including all tracts that experience nonzero ground shaking allows better estimation of zero ignition counts. For loss estimation and policy analysis, it is important to be able to estimate where ignitions are *not* likely to occur, as well as how many there will be in areas where they do occur. In the future, as more earthquakes occur, the approach presented in this report can be repeated, hopefully resulting in the earthquake indicator covariate becoming insignificant. More data would also make it possible to split the dataset into training and validation portions so that the predictive capability of the models can be better assessed. The current dataset had too few observations with counts great than one to merit that exercise.

SECTION 8

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APPENDIX A.

IGNITIONS USED IN DATASETS A AND B

Earthquake	Date	Time	Address	City	Zip code	Lat.	Long.	Source	Modifications during geocoding	Match
Coalinga	5.2.83	16:50	260 N 5th St	Coalinga	93210	36.140	-120.361	1	Was "260 Coalinga Plaza"	
Coalinga	5.2.83	20:00	205 South Joaquin St	Coalinga	93210	36.135	-120.370	1		
Coalinga	5.2.83	23:59	1080 South Joaquin St	Coalinga	93210	36.135	-120.370	1		
Morgan Hill	4.24.84	13:31	6200 Santa Teresa Blvd	San Jose	95119	37.237	-121.804	2	Was "Santa Teresa Blvd and Cottle Ave"	
Morgan Hill	4.24.84	13:54	67 Mount Hamilton Rd	San Jose	95140	37.346	-121.721	2		S
Morgan Hill	4.24.84	15:13	31 Chestnut Ct	Morgan Hill	95037	37.093	-121.635	2	Changed from St.	
Morgan Hill	4.24.84	15:42	3042 Driftwood Dr	San Jose	95128	37.298	-121.948	2	Added Dr.	
Morgan Hill	4.24.84	18:36	17455 Monterey St	Morgan Hill	95037	37.129	-121.654	2		
Morgan Hill	5.4.84	NA	22200 Mount Eden Rd	Saratoga	95070	37.272	-122.061	2		
N. Palm Springs	7.8.86	3:48	Palm Canyon Dr	Cathedral City	92234	33.780	-116.466	3	Was "E. Palm Canyon St."	S
Whittier Nar.	NA	NA	7041 Elmer Ave	Whittier	90602	33.978	-118.047	4	Added Ave.	
Whittier Nar.	NA	NA	16402 S Muriel Ave	Compton	90221	33.885	-118.201	4	Added S and Ave	
Whittier Nar.	NA	NA	1917 Nowell Ave	Rowland Heights	91748	33.983	-117.890	4	Was "1917 Howell Ave."	C
Whittier Nar.	NA	NA	4874 E Gage Ave	Bell	90201	33.977	-118.178	4	Added E., Ave.	
Whittier Nar.	NA	NA	543 Vallombrosa Dr	Pasadena	91107	34.136	-118.076	4	Added Dr.	
Whittier Nar.	NA	NA	6208 Oxsee Ave	Whittier	90606	33.988	-118.062	4	Added Ave.	
Whittier Nar.	NA	NA	330 S McBride Ave	Los Angeles	90022	34.033	-118.168	4	Added S, Ave. City was "East LA"	
Whittier Nar.	NA	NA	6920 E Slauson Ave	Commerce	90040	33.981	-118.140	4	Added E. and Ave.	
Whittier Nar.	NA	NA	16901 Valley View Ave	La Mirada	90638	33.878	-118.029	4	Added Ave. City was "Cerritos"	
Whittier Nar.	NA	NA	9102 Bermudez St	Pico Rivera	90660	33.971	-118.102	4	Added St.	
Whittier Nar.	NA	NA	5954 S Maywood	Huntington Park	90255	33.985	-118.203	4	Added S	S
Whittier Nar.	NA	NA	5505 Harker Ave	Temple	91780	34.099	-118.071	4	Added Ave.	
Whittier Nar.	NA	NA	5151 State University Dr	Los Angeles	90063	34.063	-118.171	4	Was "Cal. State Univ. LA"	S
Whittier Nar.	NA	NA	1007 W 69th St	Los Angeles	90044	33.977	-118.292	4	City was "Hyde Park"	
Whittier Nar.	NA	NA	2021 Dracena Dr	Los Feliz	90027	34.108	-118.290	4	Made Dracena Dr.	
Whittier Nar.	NA	NA	17835 Ventura Blvd	Los Angeles	91316	34.163	-118.521	4	Added Blvd. City was "Encino"	
Whittier Nar.	NA	NA	3937 Gibralter Ave	Los Angeles	90008	34.016	-118.354	4	Added Ave. City was "Baldwin Hills"	Z
Whittier Nar.	NA	NA	13519 Rye St	Sherman Oaks	91423	34.151	-118.428	4		
Whittier Nar.	NA	NA	972 Palo Verde Ave	Pasadena	91107	34.156	-118.111	4	Added Ave.	S
Whittier Nar.	NA	NA	1340 Vandyke Rd	San Marino	91108	34.121	-118.115	4	Added Rd.	Z
Loma Prieta	10.17.89	17:10	354 Byxbee St	San Francisco	94132	37.776	-122.449	5, 6		
Loma Prieta	10.17.89	17:15	3739 Loyola Terrace	San Francisco	94117	37.804	-122.444	5, 6		S
Loma Prieta	10.17.89	17:24	3701 Divisadero St	San Francisco	94123	37.750	-122.462	5, 6		
Loma Prieta	10.17.89	18:45	69 Castenada Ave	San Francisco	94116	37.731	-122.383	5, 6		
Loma Prieta	10.17.89	20:00	445 Bay Shore Blvd	San Francisco	94124	37.715	-122.473	5, 6	Was "Bayshore Blvd"	Z
Loma Prieta	10.17.89	21:30	150 Font Blvd	San Francisco	94132	37.778	-122.423	5, 6		
Loma Prieta	10.17.89	22:05	428 Grove St	San Francisco	94102	37.735	-122.438	5, 6		

Earthquake	Date	Time	Address	City	Zip code	37.721	-122.469	Source	Modifications during geocoding	Match
Loma Prieta	10.17.89	22:31	965 Chenery St	San Francisco	94131	37.753	-122.506	5, 6		
Loma Prieta	10.17.89	23:27	3999 Noriega St	San Francisco	94122	37.769	-122.450	5, 6		
Loma Prieta	10.17.89	23:31	630 Cole St	San Francisco	94117	37.755	-122.421	5, 6	Was "630 & 632 Cole St."	
Loma Prieta	10.18.89	1:30	1138 Valencia St	San Francisco	94110	37.773	-122.451	5, 6		
Loma Prieta	10.18.89	8:17	2095 Hayes St	San Francisco	94117	37.777	-122.444	5, 6		
Loma Prieta	10.18.89	9:43	1954 McAllister St	San Francisco	94115	37.789	-122.459	5, 6		
Loma Prieta	10.18.89	10:18	3867 Jackson St	San Francisco	94118	37.765	-122.463	5, 6		
Loma Prieta	10.18.89	11:30	1256 6th Ave	San Francisco	94112	37.782	-122.475	5, 6		S
Loma Prieta	10.18.89	13:06	300 16th Ave	San Francisco	94118	37.784	-122.428	5, 6		
Loma Prieta	10.18.89	16:37	5 Galilee Lane	San Francisco	94115	37.794	-122.406	5, 6		
Loma Prieta	10.18.89	17:01	754 Grant Ave	San Francisco	94108	37.774	-122.489	5, 6		
Loma Prieta	10.18.89	17:57	818 30th Ave	San Francisco	94121	37.790	-122.414	5, 6		
Loma Prieta	10.18.89	20:22	1040 Bush St	San Francisco	94109	37.788	-122.418	5, 6		
Loma Prieta	10.18.89	20:48	1020 Larkin St	San Francisco	94109	37.790	-122.419	5, 6		
Loma Prieta	10.18.89	20:54	1308 Larkin St	San Francisco	94109	37.787	-122.423	5, 6		
Loma Prieta	10.18.89	20:56	1 Daniel Burnham Ct	San Francisco	94109	37.788	-122.401	5, 6		
Loma Prieta	10.19.89	0:33	74 New Montgomery St	San Francisco	94105	37.788	-122.401	5, 6		
Loma Prieta	10.19.89	3:12	74 New Montgomery St	San Francisco	94105	37.779	-122.406	5, 6		
Loma Prieta	10.19.89	12:02	241 6th St	San Francisco	94103	37.789	-122.406	5, 6		
Loma Prieta	10.19.89	14:16	237 Post St	San Francisco	94108	37.787	-122.418	5, 6		S
Loma Prieta	10.19.89	15:30	989 Post St	San Francisco	94109	37.804	-122.410	5, 6		
Loma Prieta	10.19.89	NA	1950 Stockton St	San Francisco	94133	37.785	-122.464	6		
Loma Prieta	10.19.89	NA	172 6th Ave	San Francisco	94118	37.788	-122.418	6		
Loma Prieta	10.19.89	NA	1040 Sutter St	San Francisco	94109	37.731	-122.383	6		
Loma Prieta	10.20.89	NA	5 George Ct	San Francisco	94124	37.727	-122.427	6	Changed St. to Ct.	
Loma Prieta	10.20.89	NA	299 Peru Ave	San Francisco	94112	37.772	-122.424	6		
Loma Prieta	10.20.89	NA	48 Waller St	San Francisco	94102	36.967	-122.030	6		
Loma Prieta	NA	NA	138 Myrtle Ave	Santa Cruz	95060	37.867	-122.270	7		
Loma Prieta	NA	NA	2037 Durant Ave	Berkeley	94704	34.286	-118.438	7, 8		
Northridge	1.17.94	4:36	1118 W 3rd St	Los Angeles	91340	34.250	-118.520	9		O
Northridge	1.17.94	4:37	17730 W Lassen St	Los Angeles	91325	34.250	-118.595	9		S
Northridge	1.17.94	4:37	21213 W Lassen St	Los Angeles	91311	34.208	-118.535	9		S
Northridge	1.17.94	4:40	1725 N Clear View Dr	Los Angeles	90210	34.324	-118.466	9		O
Northridge	1.17.94	4:40	7607 N Canby Ave	Los Angeles	91335	34.284	-118.387	9	Number was 75027	S
Northridge	1.17.94	4:53	15455 N Glenoaks Blvd	Los Angeles	91342	34.267	-118.461	9		S
Northridge	1.17.94	4:58	11742 Luanda St	Los Angeles	91342	34.261	-118.600	9		
Northridge	1.17.94	5:00	10845 N Burnet Ave	Los Angeles	91345	34.173	-118.557	9		S, O
Northridge	1.17.94	5:08	21601 San Jose St	Los Angeles	91311	34.208	-118.600	9		
Northridge	1.17.94	5:12	19443 W Ventura Blvd	Los Angeles	91356	34.000	-118.280	9		S, O
Northridge	1.17.94	5:19	21618 W Saticoy St	Los Angeles	91303	34.269	-118.312	9	Number was 21617	S, O
Northridge	1.17.94	5:19	365 W 47th Pl	Los Angeles	90037	34.309	-118.468	9		O

Earthquake	Date	Time	Address	City	Zip code	37.721	-122.469	Source	Modifications during geocoding	Match
Northridge	1.17.94	5:26	10949 N Mcvine Ave	Los Angeles	91040	34.031	-118.346	9		S
Northridge	1.17.94	5:27	15445 Cobalt Ave	Los Angeles	91342	34.231	-118.603	9		S
Northridge	1.17.94	5:27	2741 S Palm Grove Ave	Los Angeles	90016	34.082	-118.304	9		
Northridge	1.17.94	5:30	8901 N Topanga Canyon Blvd	Los Angeles	91304	34.211	-118.351	9	Number was 890021	S
Northridge	1.17.94	5:33	566 N Kingsley Dr	Los Angeles	90004	34.231	-118.595	9		O
Northridge	1.17.94	5:46	7635 N Delia Ave	Los Angeles	91352	34.293	-118.562	9	Number was 7655	S
Northridge	1.17.94	5:59	8801 N Eton Ave	Los Angeles	91304	34.233	-118.594	9		S
Northridge	1.17.94	6:00	19603 W Turtle Springs Way	Los Angeles	91326	34.149	-118.430	9		S
Northridge	1.17.94	6:13	8901 N Eton Ave	Los Angeles	91304	34.096	-118.323	9		S
Northridge	1.17.94	6:26	4360 N Ventura Canyon Ave	Los Angeles	91423	34.153	-118.432	9		S
Northridge	1.17.94	6:27	6132 W De Longpre Ave	Los Angeles	90028	34.150	-118.443	9		S, O
Northridge	1.17.94	6:31	4500 N Woodman Ave	Los Angeles	91423	34.155	-118.447	9		S
Northridge	1.17.94	6:37	14225 W Ventura Blvd	Los Angeles	91423	34.114	-118.324	9		S, O
Northridge	1.17.94	6:43	4618 N Sylmar Ave	Los Angeles	91423	34.144	-118.394	9		S, O
Northridge	1.17.94	6:52	2421 N Creston Way	Los Angeles	90068	34.209	-118.413	9		S, O
Northridge	1.17.94	7:09	12036 W Ventura Blvd	Los Angeles	91604	34.149	-118.451	9		S
Northridge	1.17.94	7:55	7624 N Goodland Ave	Los Angeles	91605	34.244	-118.532	9		S
Northridge	1.17.94	8:02	14569 W Benefit St	Los Angeles	91403	33.980	-118.465	9		S, O
Northridge	1.17.94	8:16	18309 W Halsted St	Los Angeles	91325	34.271	-118.468	9		S, O
Northridge	1.17.94	8:45	119 E Anchorage St	Los Angeles	90292	34.225	-118.533	9		S, O
Northridge	1.17.94	8:46	15419 Horace St	Los Angeles	91345	34.268	-118.404	9	Number was 154419	O
Northridge	1.17.94	8:50	18403 W Malden St	Los Angeles	91325	34.202	-118.515	9	Number was 184003	S, O
Northridge	1.17.94	8:56	10885 N Jamie St	Los Angeles	91331	34.215	-118.527	9		S
Northridge	1.17.94	8:59	7237 N Anatola Ave	Los Angeles	91406	34.314	-118.475	9		S, O
Northridge	1.17.94	9:18	18100 W Strathern St	Los Angeles	91335	34.200	-118.515	9		S, O
Northridge	1.17.94	9:28	15831 W Olden St	Los Angeles	91342	34.216	-118.527	9		S, O
Northridge	1.17.94	9:37	14037 W Ventura Blvd	Los Angeles	91423	34.219	-118.507	9		S, O
Northridge	1.17.94	9:57	17515 W Enadia Way	Los Angeles	91406	33.993	-118.316	9		S
Northridge	1.17.94	10:07	8000 N Lindley Ave	Los Angeles	91335	34.191	-118.536	9		S, O
Northridge	1.17.94	10:32	17221 W Willard St	Los Angeles	91406	34.261	-118.418	9		S, O
Northridge	1.17.94	10:45	2134 W 54th St	Los Angeles	90062	34.247	-118.558	9		
Northridge	1.17.94	10:53	6660 N Reseda Blvd	Los Angeles	91335	34.149	-118.438	9		S
Northridge	1.17.94	11:01	10490 N Ilex Ave	Los Angeles	91331	34.191	-118.493	9		S, O
Northridge	1.17.94	11:11	9740 N Tunney Ave	Los Angeles	91324	34.201	-118.469	9		S, O
Northridge	1.17.94	11:45	14005 W Ventura Blvd	Los Angeles	91423	34.209	-118.536	9		S, O
Northridge	1.17.94	12:00	6626 N Hayvenhurst Ave	Los Angeles	91406	34.238	-118.446	9	Number was 662631	S, O
Northridge	1.17.94	12:02	15425 W Sherman Way	Los Angeles	91406	34.162	-118.517	9	Number was 154252	S, O
Northridge	1.17.94	12:30	7651 N Reseda Blvd	Los Angeles	91335	34.099	-118.317	9		S

Earthquake	Date	Time	Address	City	Zip code	37.721	-122.469	Source	Modifications during geocoding	Match
Northridge	1.17.94	12:45	14424 W Terra Bella St	Los Angeles	91402	34.282	-118.502	9		S, O
Northridge	1.17.94	12:59	17609 W Ventura Blvd	Los Angeles	91316	34.038	-118.378	9		S
Northridge	1.17.94	14:27	5862 W Harold Wy	Los Angeles	90028	34.157	-118.570	9	Number was 5842	S, O
Northridge	1.17.94	15:01	11700 N Balboa Blvd	Los Angeles	91344	34.139	-118.430	9		S
Northridge	1.17.94	15:40	2324 S Chariton St	Los Angeles	90034	34.096	-118.360	9		S
Northridge	1.17.94	16:12	20033 N Gypsy Ln	Los Angeles	91364	34.039	-118.390	9		S, O
Northridge	1.17.94	16:40	3845 N Bobstone Dr	Los Angeles	91423	34.101	-118.307	9		S, O
Northridge	1.17.94	17:22	7820 W Delongpre Ave	Los Angeles	90046	34.250	-118.599	9		S
Northridge	1.17.94	17:32	9108 W 25th St	Los Angeles	90034	34.276	-118.446	9		
Northridge	1.17.94	18:26	1622 N Serrano Ave	Los Angeles	90027	34.042	-118.395	9		
Northridge	1.17.94	18:28	21505 Lassen St	Los Angeles	91311	34.266	-118.500	9	Number was 215005	O
Northridge	1.17.94	18:37	834 W Omelveny Ave	Los Angeles	91340	34.033	-118.391	9	Number was 634	S
Northridge	1.17.94	19:00	2400 S Beverly Dr	Los Angeles	90034	34.008	-118.328	9		O
Northridge	1.17.94	19:17	10763 N Forbes Ave	Los Angeles	91344	34.018	-118.302	9		S
Northridge	1.17.94	19:23	3024 S Livonia Ave	Los Angeles	90034	34.263	-118.511	9		S, O
Northridge	1.17.94	19:42	4208 S 10th Ave	Los Angeles	90008	34.008	-118.329	9	Number was 42082	S, O
Northridge	1.17.94	19:52	1340 W Exposition Blvd	Los Angeles	90018	34.239	-118.602	9		S
Northridge	1.17.94	20:21	10630 N Louise Ave	Los Angeles	91344	34.235	-118.528	9		S, O
Northridge	1.17.94	21:49	4230 S 11th Ave	Los Angeles	90008	34.235	-118.549	9		S, O
Northridge	1.17.94	22:11	9248 Owensmouth Ave	Los Angeles	91311	34.235	-118.528	9	Number was 9250	O
Northridge	1.17.94	22:19	18111 W Nordhoff St	Los Angeles	91325	34.249	-118.287	9		S
Northridge	1.17.94	22:22	19116 Nordhoff St	Los Angeles	91324	34.039	-118.454	9	Was "Nordhoff/Vanalden"	O
Northridge	1.17.94	22:32	18111 W Nordhoff St	Los Angeles	91325	33.993	-118.321	9		S
Northridge	1.17.94	22:52	7138 W Greeley St	Los Angeles	91042	34.031	-118.493	9		S, O
Northridge	1.17.94	22:55	1818 S Stoner	Los Angeles	90025	34.018	-118.491	9	Added Ave.	S
Northridge	1.17.94	23:14	10157 Wisner Ave	Los Angeles	91345	34.037	-118.467	9		O
Northridge	1.17.94	23:27	2517 W 54th St	Los Angeles	90043	34.031	-118.505	9		O
Northridge	1.17.94	4:51	908 14 St	Santa Monica	90403	33.717	-118.069	9		
Northridge	1.17.94	5:11	1446 7 St	Santa Monica	90401	36.140	-120.361	9		
Northridge	1.17.94	12:00	3232 Broadway	Santa Monica	90404	36.135	-120.370	9		
Northridge	1.17.94	15:45	457 Lincoln Blvd	Santa Monica	90402	36.135	-120.370	9		
Northridge	1.24.94	10:04	16835 Bayview Dr	Sunset Beach	90742	37.237	-121.804	10		

Notes:

- Sources. 1=Scawthorn and Donelan (1984), 2=Scawthorn et al. (1985), 3=EERI (1986), 4=Wiggins (1988), 5=City of San Francisco (1989), 6=Mohammadi et al. (1992), 7=Olson et al. (2003), 8=C. Scawthorn personal communication (2007), 9=Scawthorn et al. (1998), and 10=Orange County Fire Authority.
- NA = not available
- Zip codes, latitude, and longitude values were not provided in the original data. They were added during the geocoding process.

- Match indicates if the geocoding provided a match at a level other than the specific building. S=Street level, Z= zip code level, C=city level. In the Match column for Northridge fires, "O" indicates that the geocoded census tract matches that provided in the original data.
- Coalinga. In addition to those listed in the table, one fire mentioned in Scawthorn and Donelan (1984) was not included because it did not require fire department help to extinguish. There were about 15 grass fires in the surrounding countryside that were not included because they were not structural fires.
- Morgan Hill. In addition to those listed in the table, two fires mentioned in Scawthorn et al. (1985) were not included because they were grass fires and one was not included because it did not require fire department help to extinguish.
- North Palm Springs. In addition to those listed in the table, two fires mentioned in EERI (1986) were not included because they were not structural fires and one was not included because it did not require fire department help to extinguish.
- Whittier Narrows. In addition to those listed in the table, three fires mentioned in Wiggins (1988) were not included because they were not structural fires, five were not included because they did not require fire department help to extinguish, and two were not included because no location information was provided. Wiggins (1988) also reports that there were 8 additional incidents in the Los Angeles County fire department area, but no locations were provided, so they were not included in this dataset.
- Loma Prieta. In addition to those listed in the table, seven fires mentioned in City of San Francisco (1989) were not included because they were not new ignitions, but fires that began by spreading from neighboring buildings. Fires listed in the two sources are the same. The six listed only in Mohammadi et al. (1992) were likely not included in City of San Francisco (1989) because that included only ignitions in the first 72 hours post-earthquake. Olson et al. (2003) indicates San Francisco had 27 structural fires in the 7 hours between the time of the earthquake and midnight, which does not match the City of San Francisco (1989) source. Olson et al. (2003) reported that there was one major fire in Berkeley (C. Scawthorn provided the location by personal communication), none in Oakland, and one in Santa Cruz. It also indicates there were about 2 dozen buildings destroyed by fire in Santa Cruz County, but no specific data was provided about that.
- Northridge. In addition to those listed in the table, four Santa Monica fires listed in Scawthorn et al. (1998) were not listed as being "earthquake-related" based on the ignition factor and contributing factor fields, so they were not included. In the Match column for Northridge fires, "O" indicates that the geocoded census tract matches that provided in the original data.

APPENDIX B. DESCRIPTIVE STATISTICS FOR DATASETS A AND B

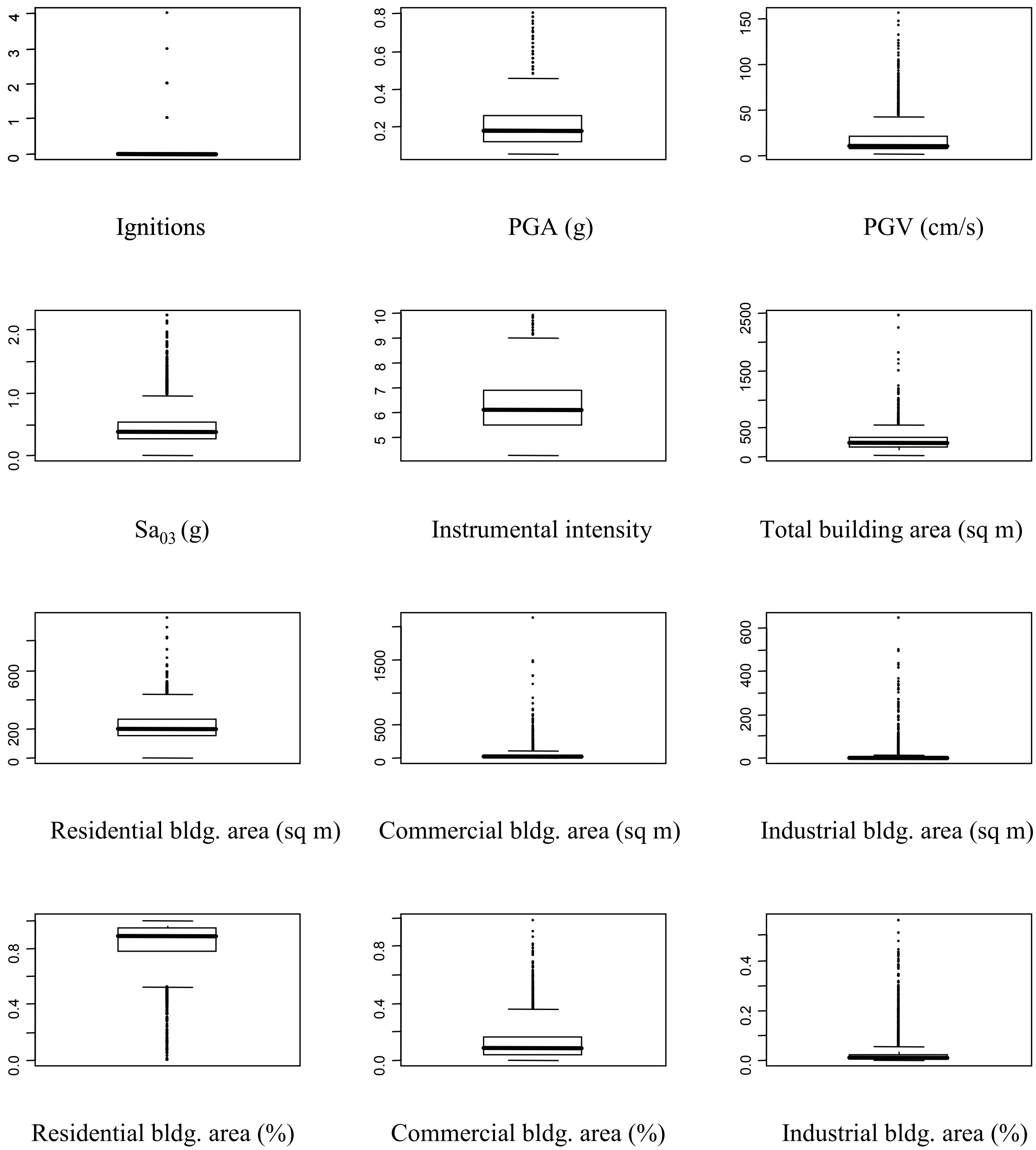
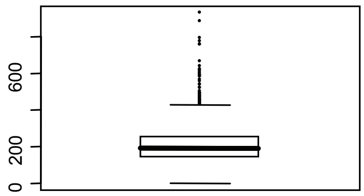
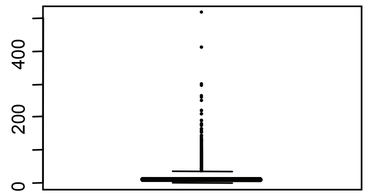


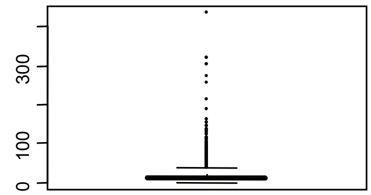
Figure B.1. Boxplots of covariates for Dataset A (1st part of 6)



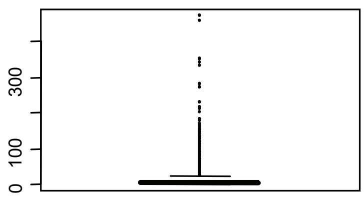
Wood bldg. area (sq m)



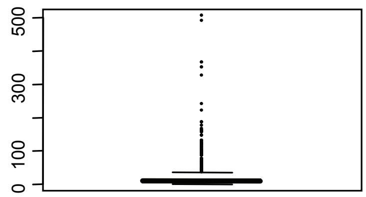
Steel bldg. area (sq m)



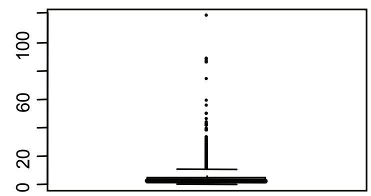
Concrete bldg. area (sq m)



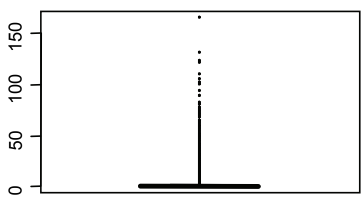
Pre-stressed concrete bldg. area (sq m)



Reinforced masonry bldg. area (sq m)



URM bldg. area (sq m)



Mobile home bldg. area (sq m)

Figure B.1. Boxplots of covariates for Dataset A (2nd part of 6)

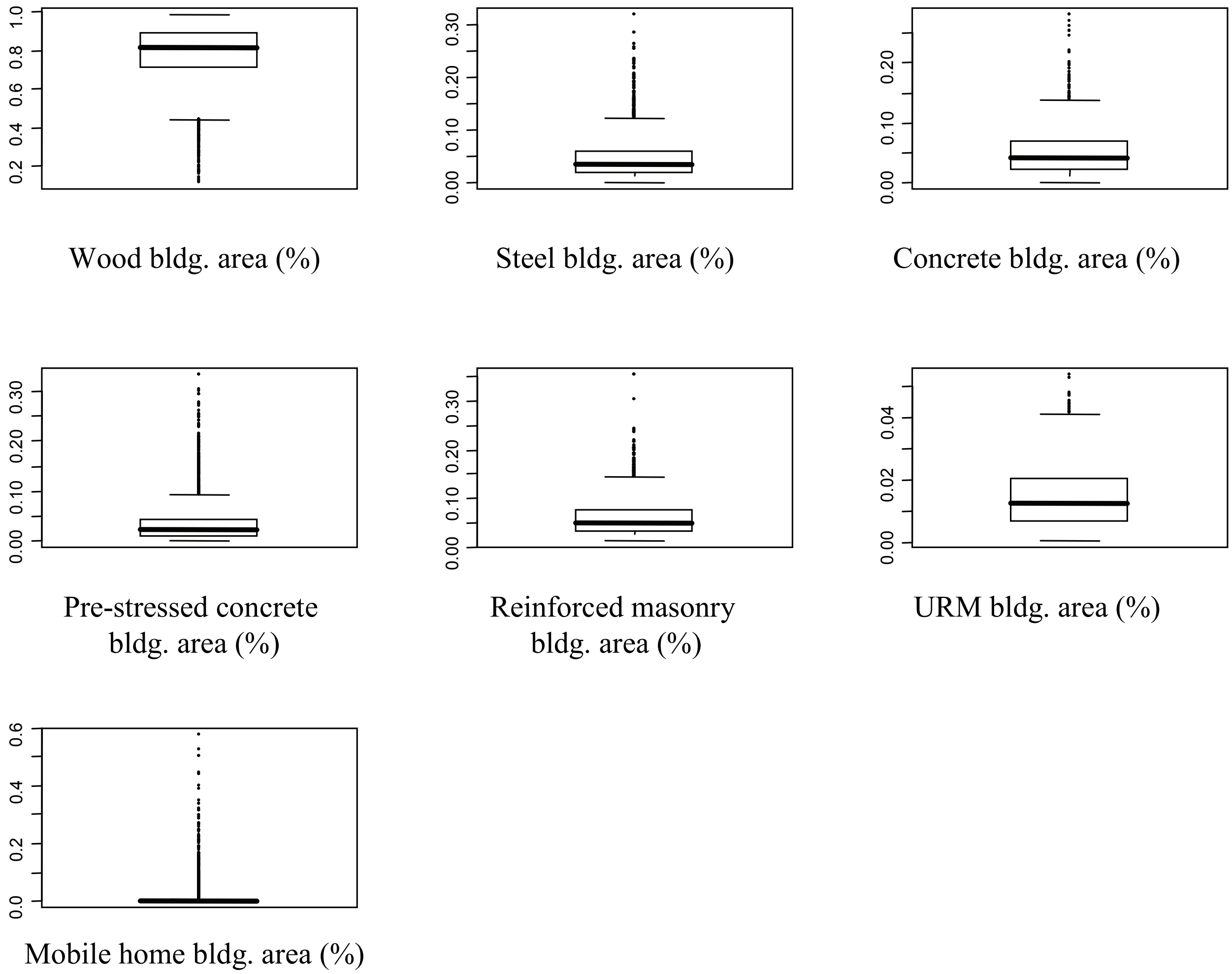
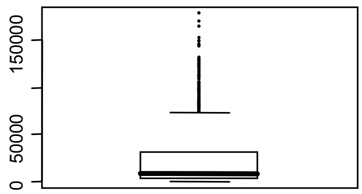
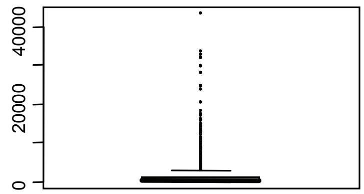


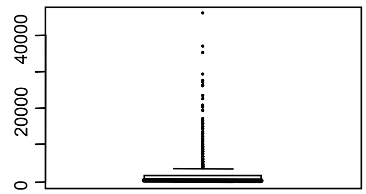
Figure B.1. Boxplots of covariates for Dataset A (3rd part of 6)



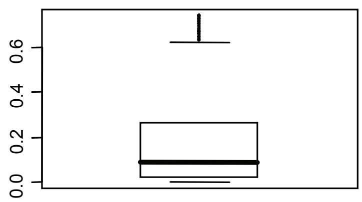
W1 bldg. area
with ≥ slight damage (sq m)



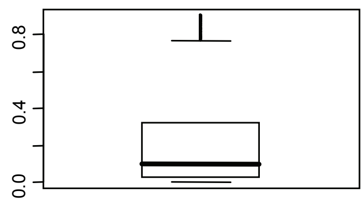
C2L bldg. area
with ≥ slight damage (sq m)



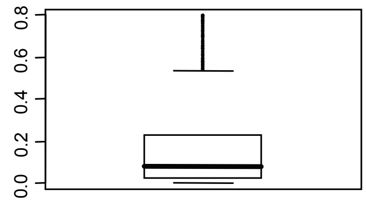
RM1L bldg. area
with ≥ slight damage (sq m)



W1 bldg. area
with ≥ slight damage (%)



C2L bldg. area
with ≥ slight damage (%)



RM1L bldg. area
with ≥ slight damage (%)

Figure B.1. Boxplots of covariates for Dataset A (4th part of 6)

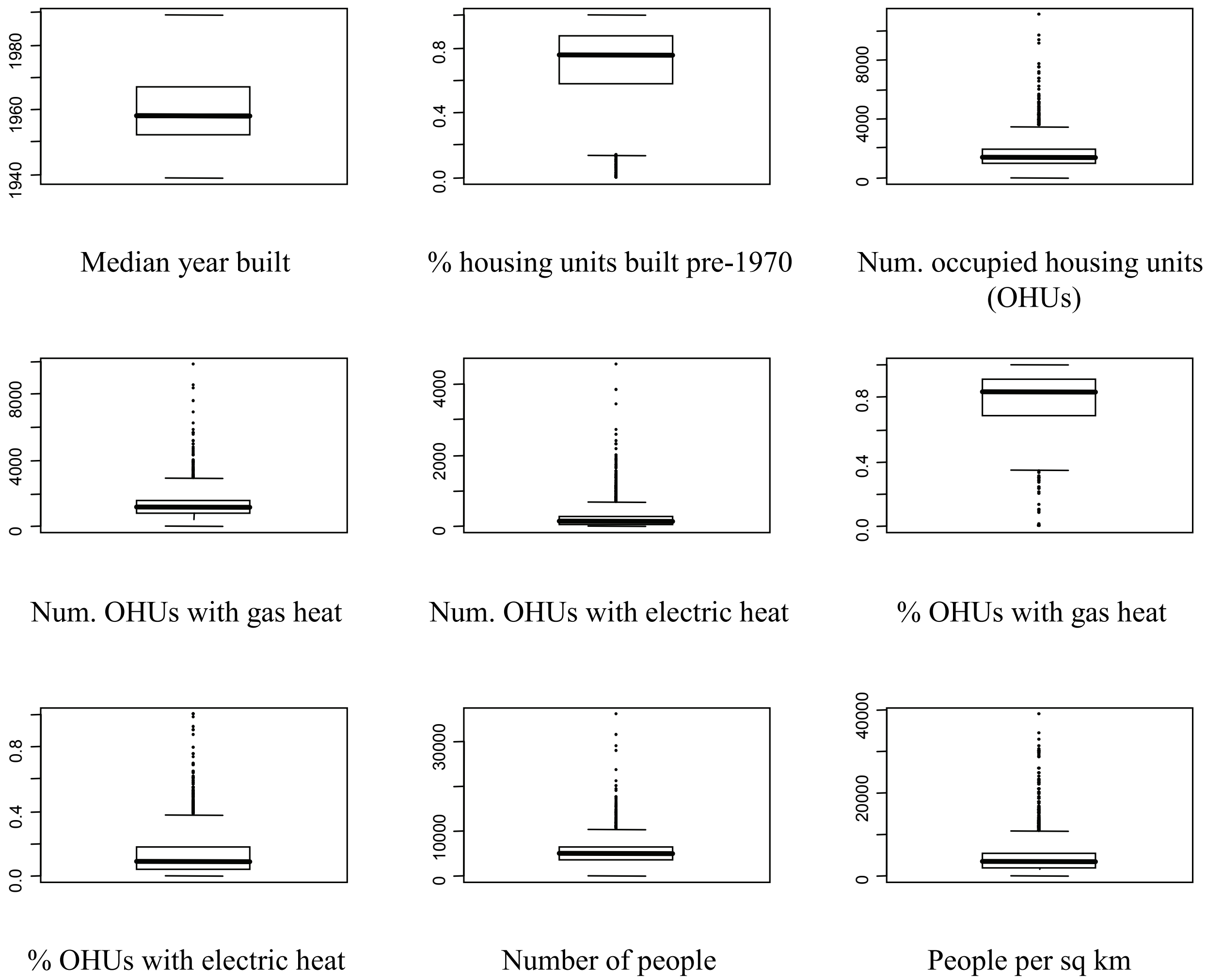
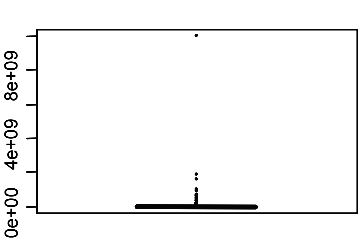
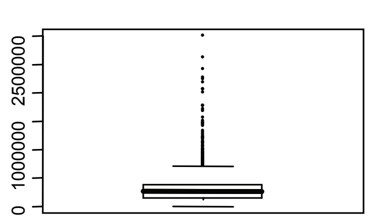


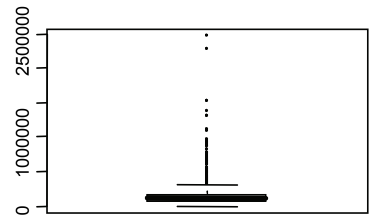
Figure B.1. Boxplots of covariates for Dataset A (5th part of 6)



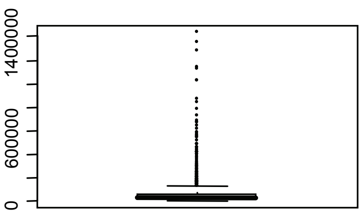
Tract area (sq m)



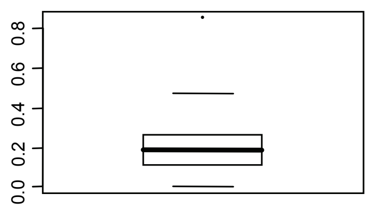
Low-intensity residential area (sq m)



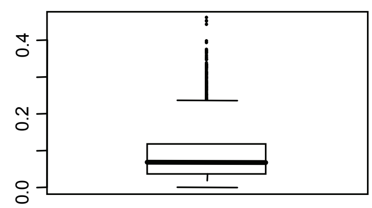
High-intensity residential area (sq m)



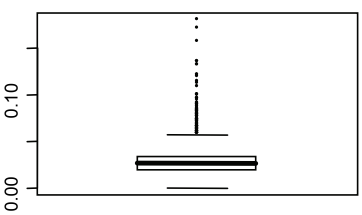
Commercial, industrial, transportation area (sq m)



Low-intensity residential area (%)



High-intensity residential area (%)



Commercial, industrial, transportation area (%)

Figure B.1. Boxplots of covariates for Dataset A (6th part of 6)

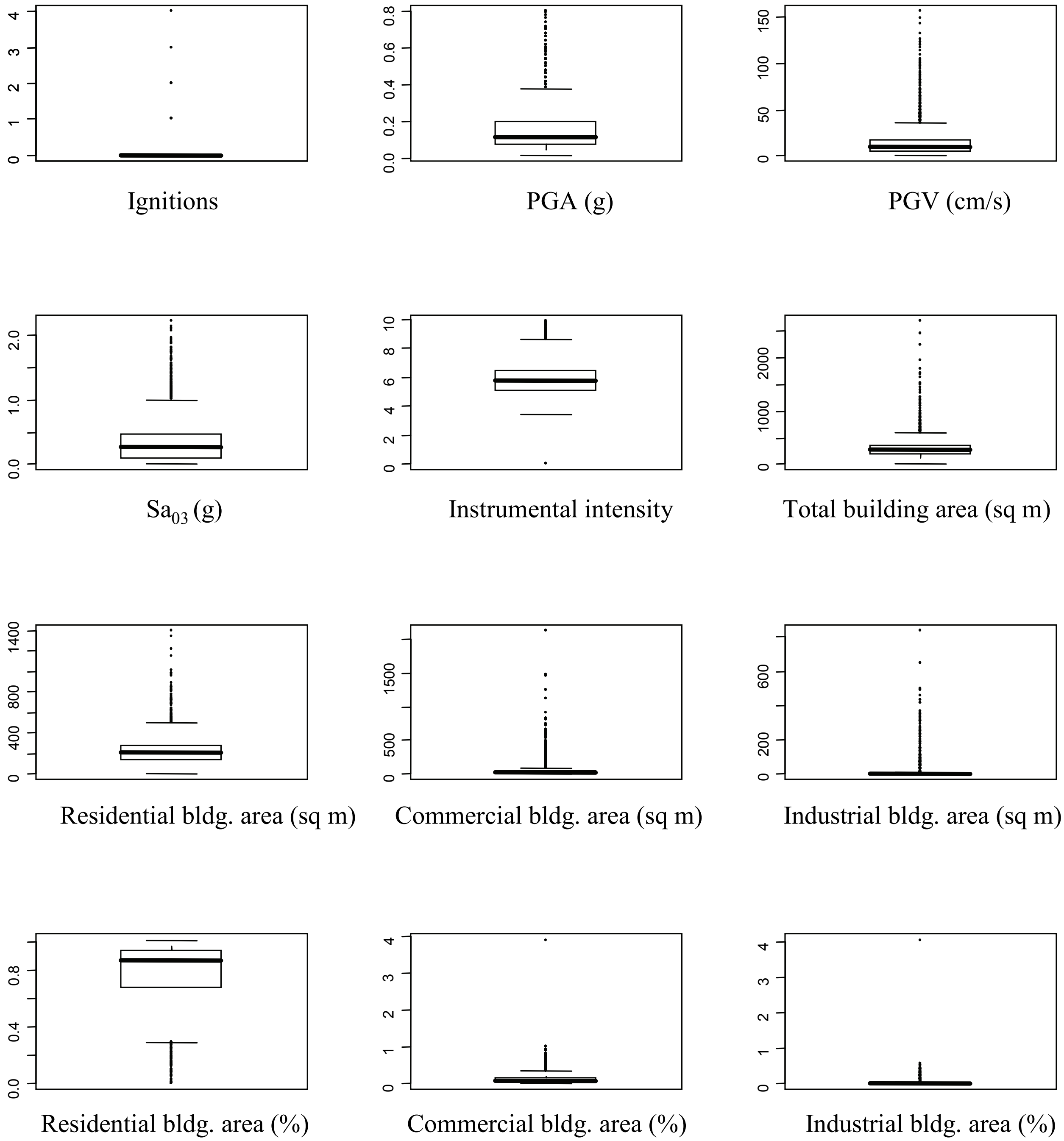


Figure B.2. Boxplots of covariates for Dataset B (1st part of 6)

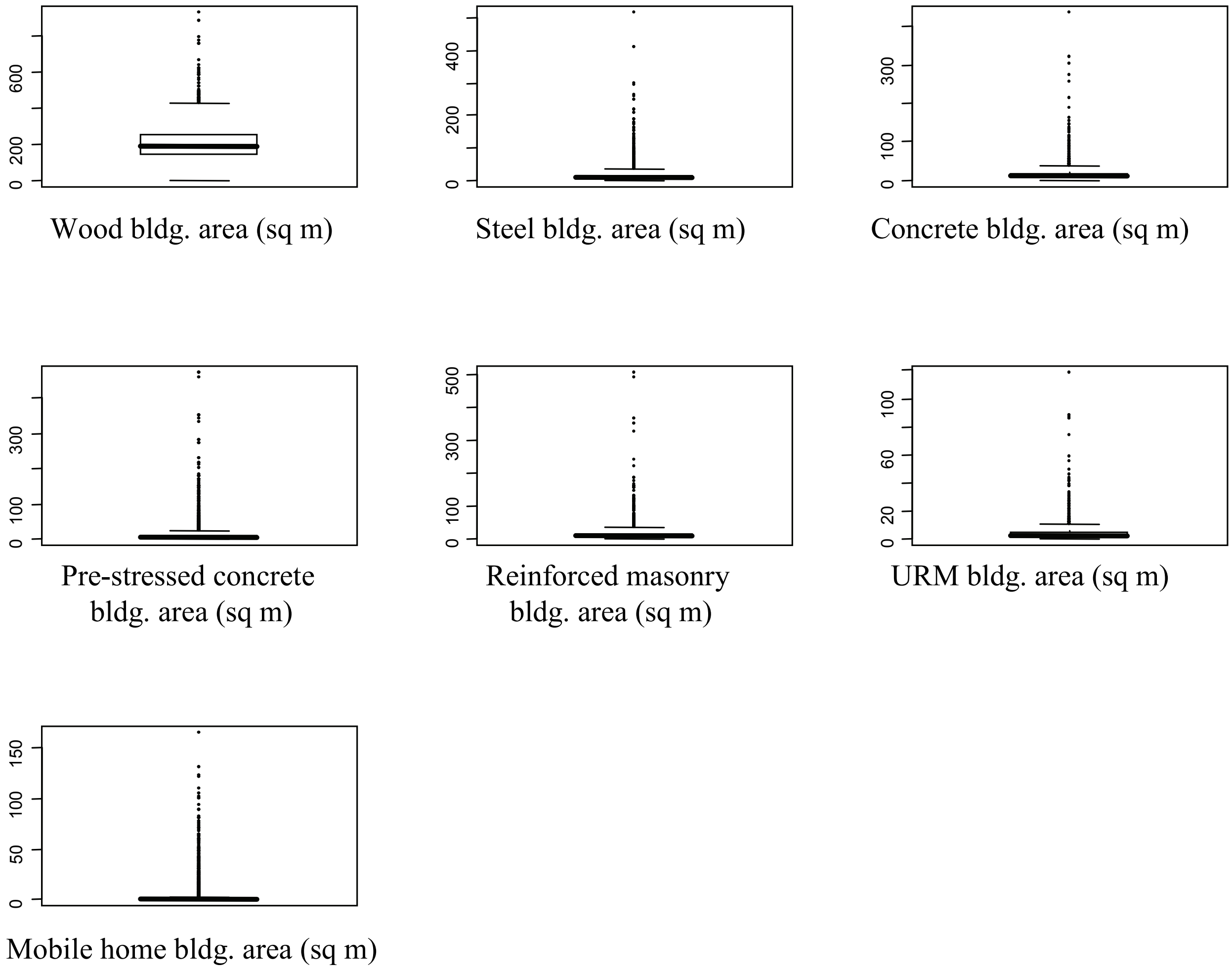


Figure B.2. Boxplots of covariates for Dataset B (2nd part of 6)

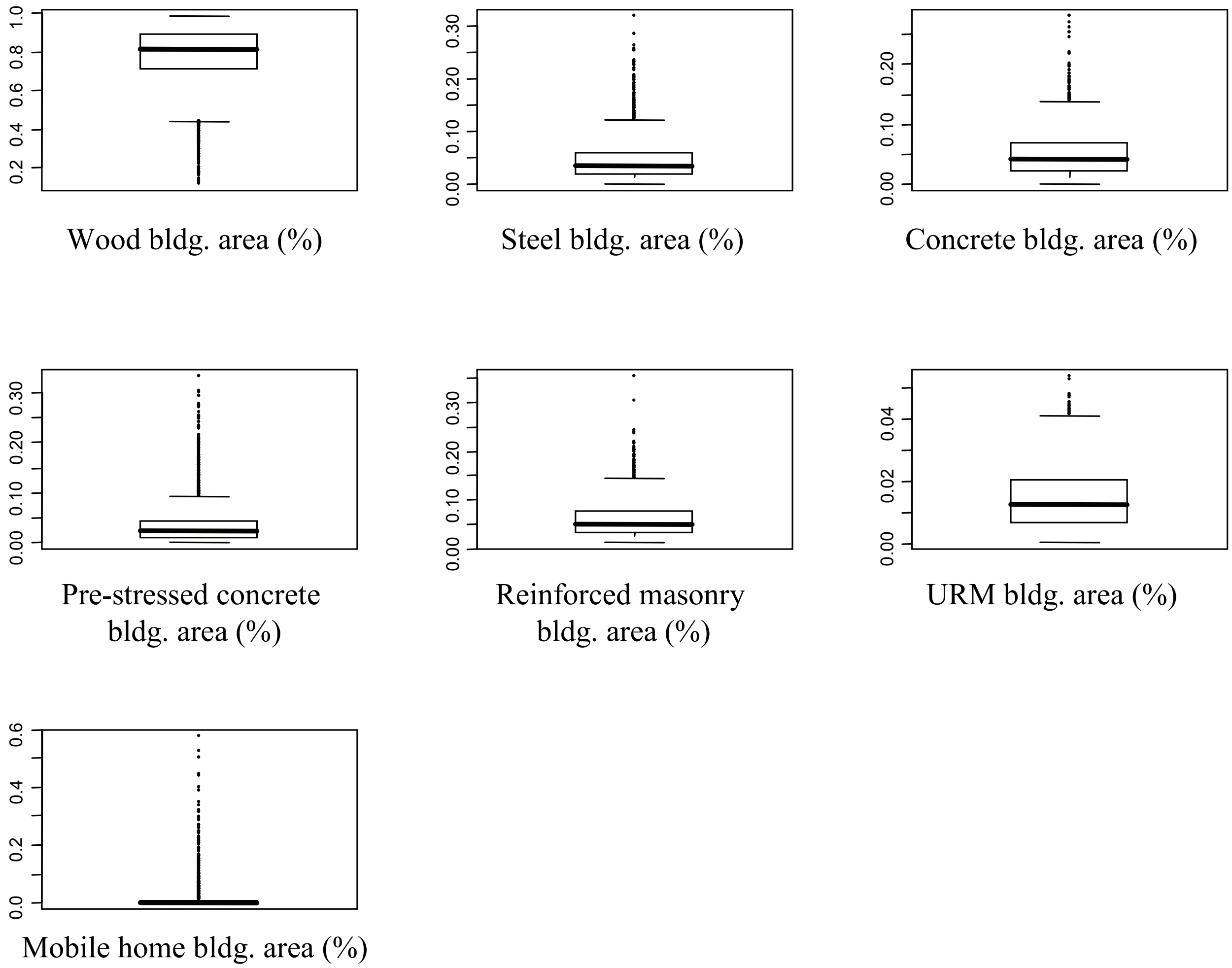


Figure B.2. Boxplots of covariates for Dataset B (3rd part of 6)

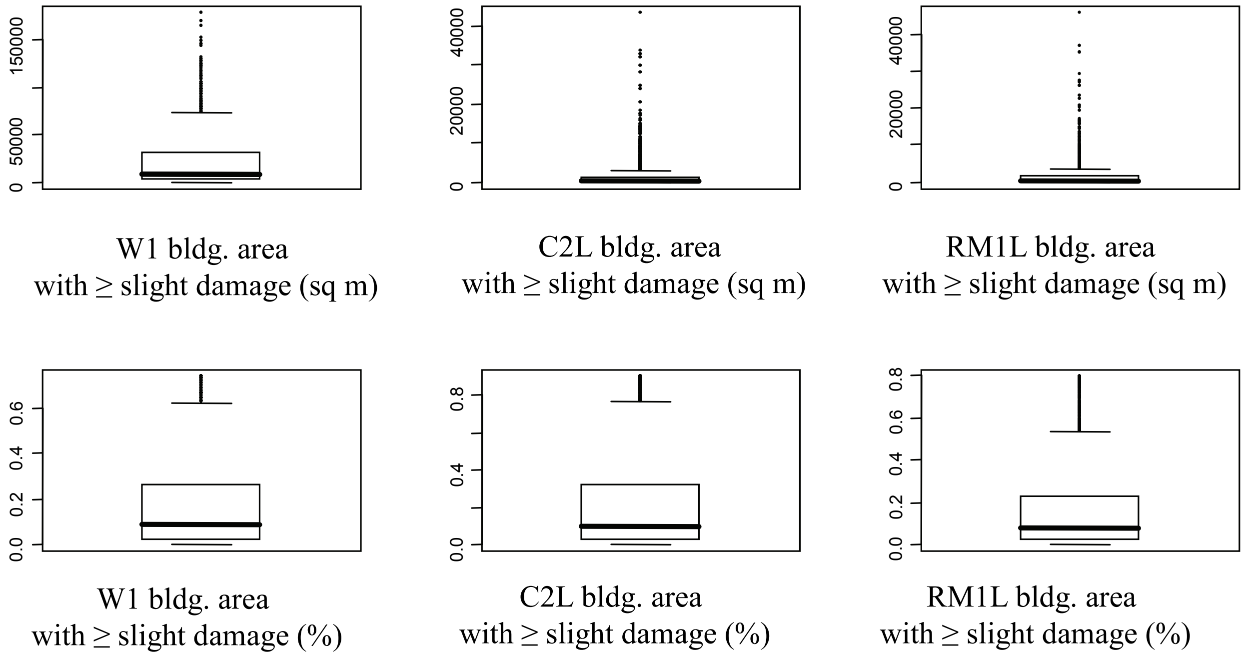


Figure B.2. Boxplots of covariates for Dataset B (4th part of 6)

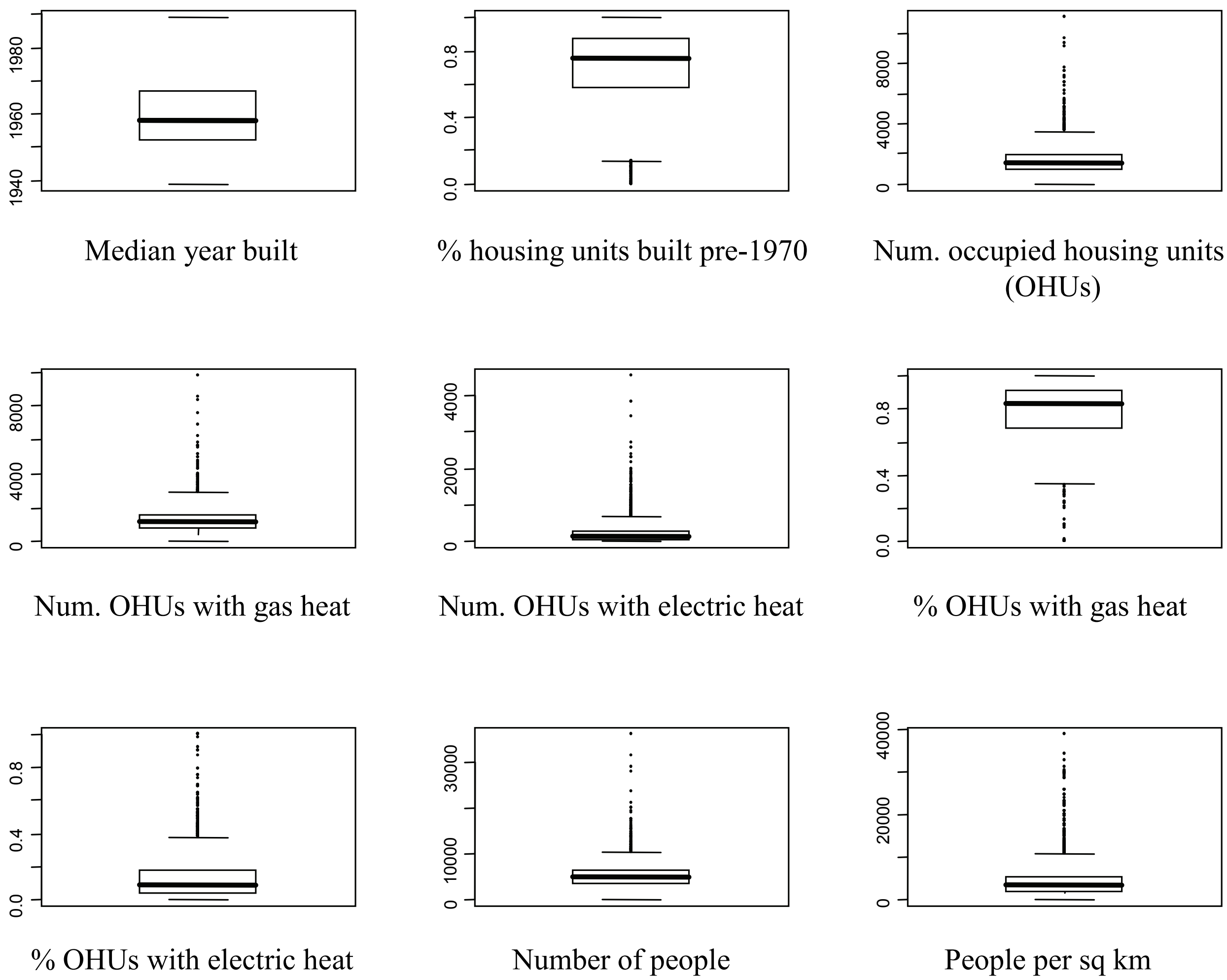


Figure B.2. Boxplots of covariates for Dataset B (5th part of 6)

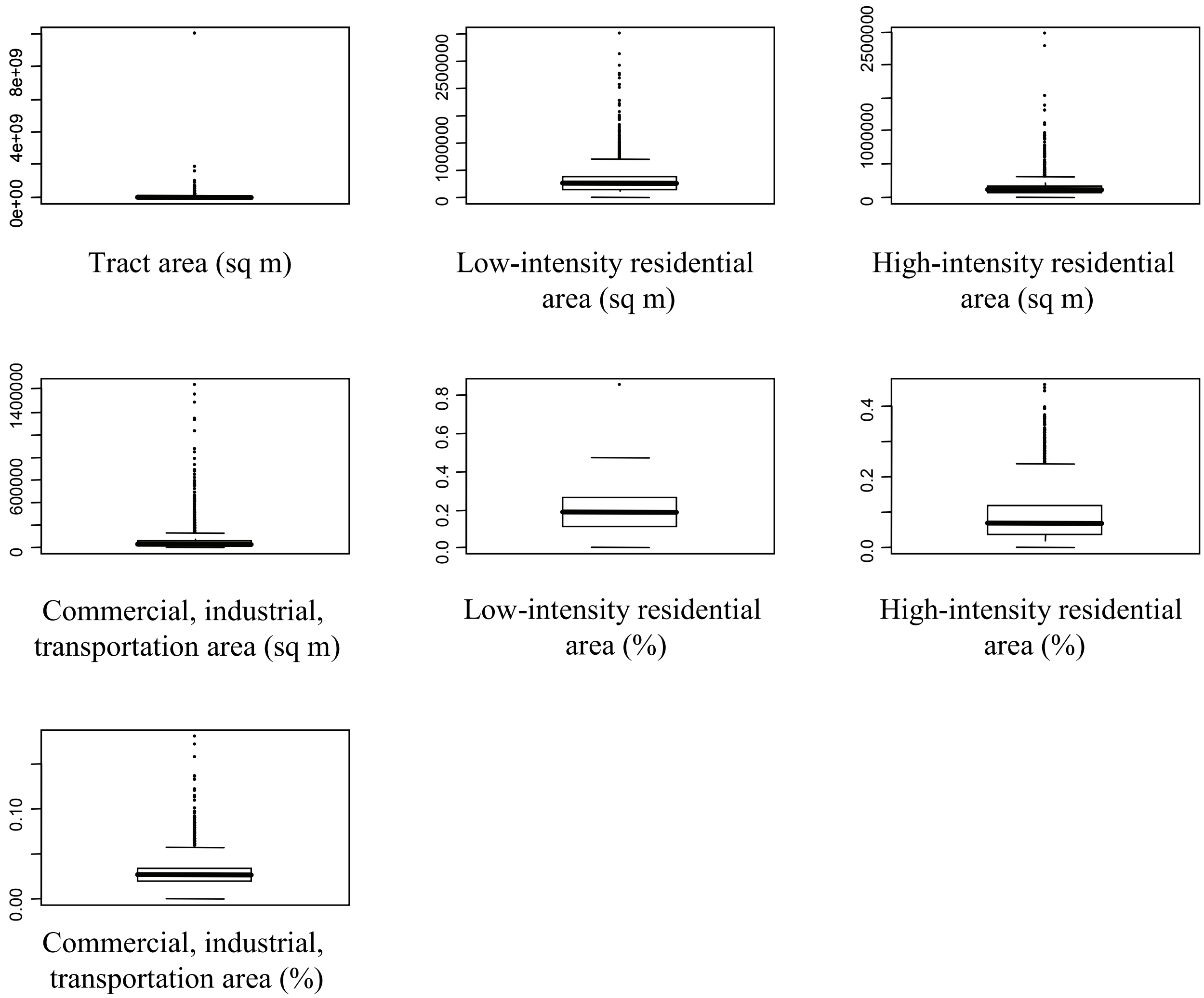


Figure B.2. Boxplots of covariates for Dataset B (6^{th} part of 6)

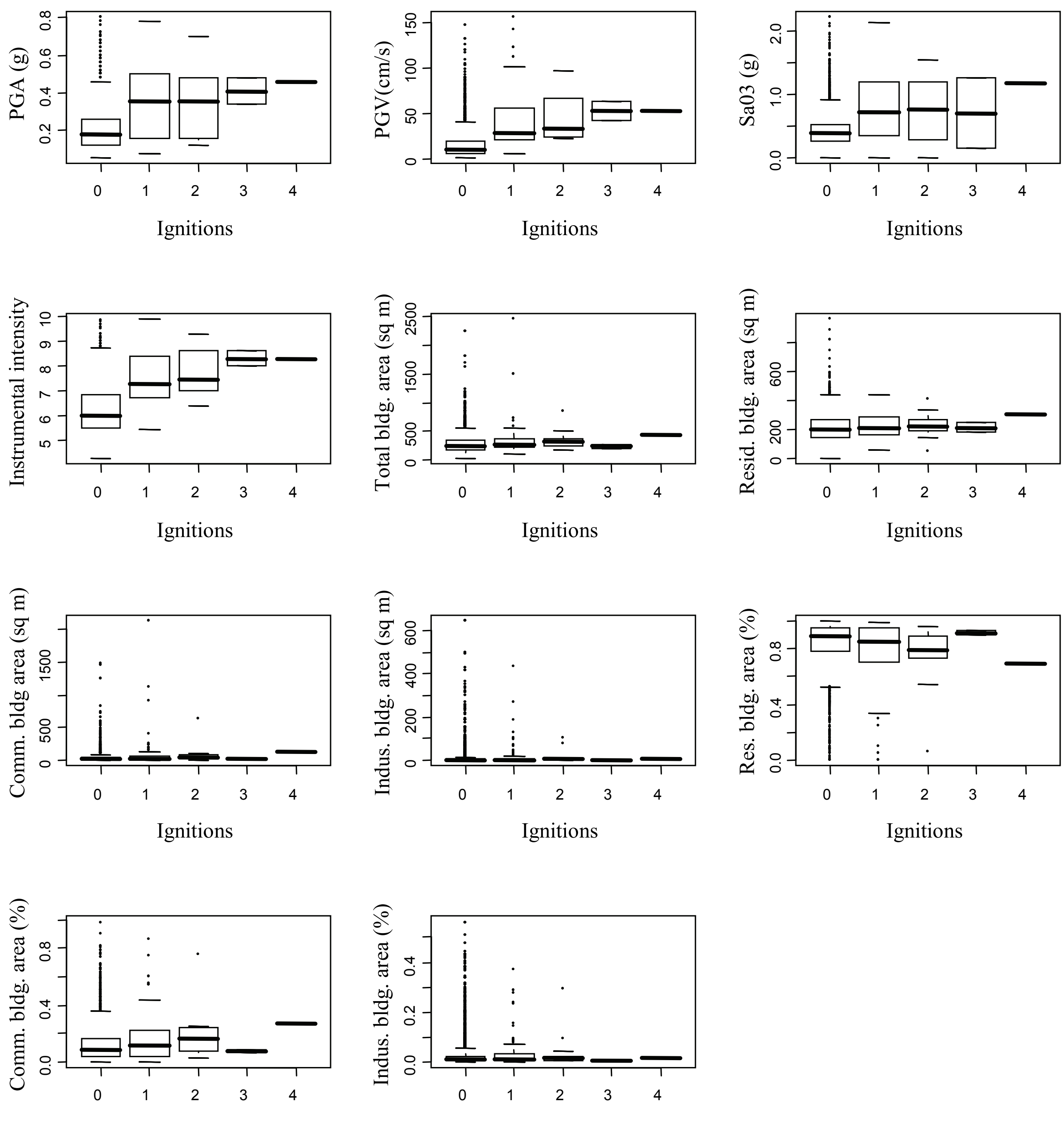


Figure B.3. Boxplots of covariate values vs. ignitions for Dataset A (1st part of 6)

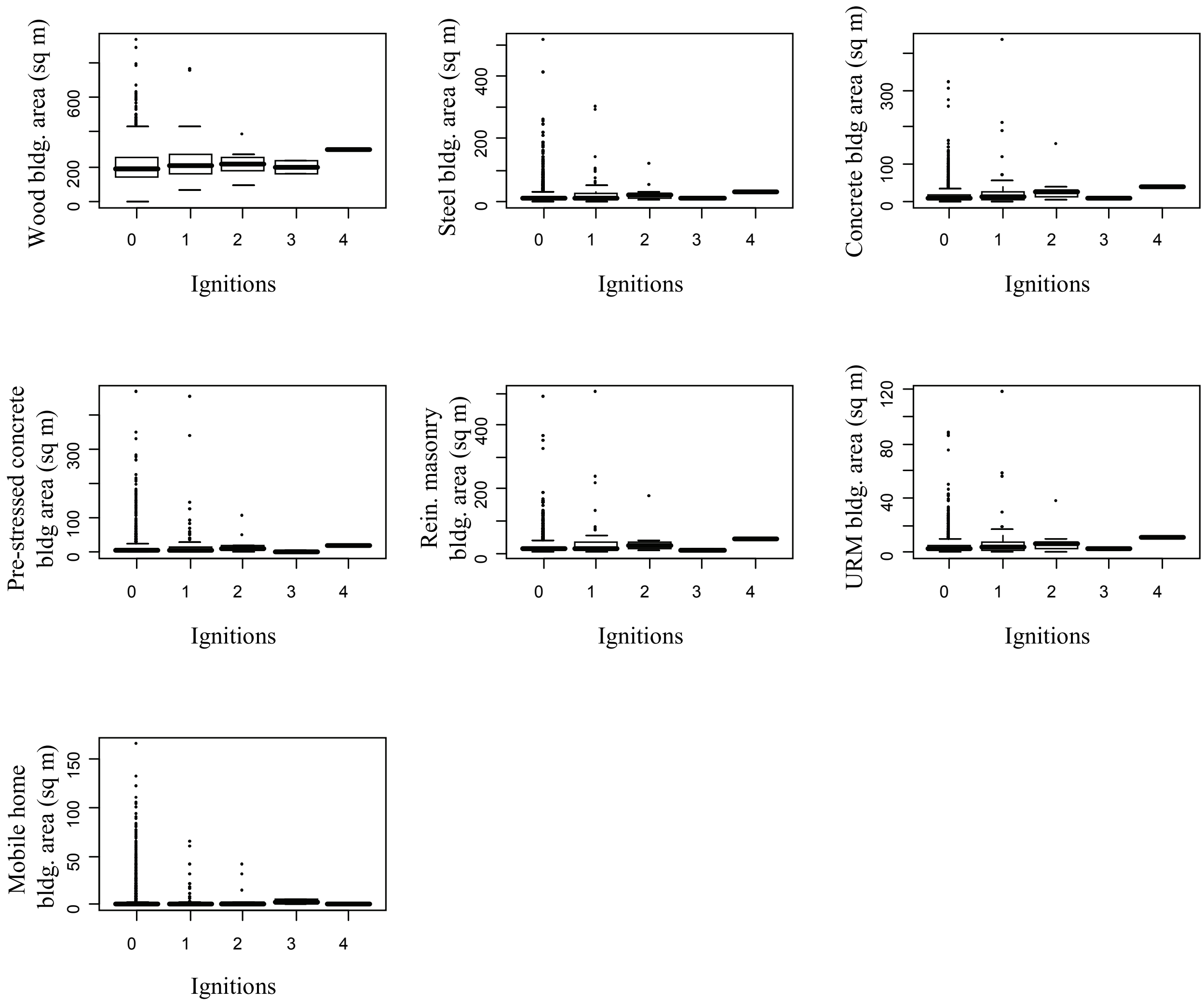


Figure B.3. Boxplots of covariate values vs. ignitions for Dataset A (2nd part of 6)

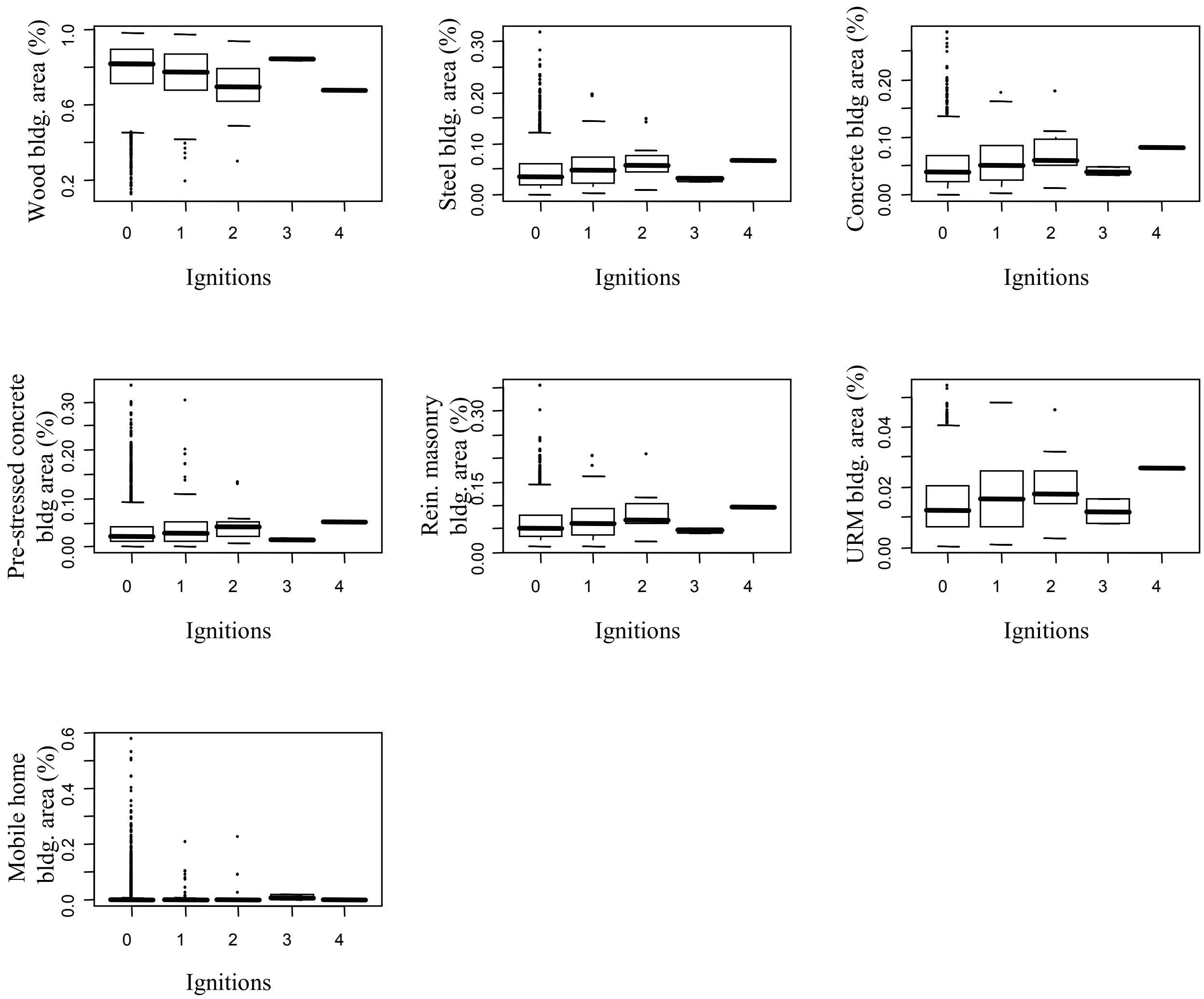


Figure B.3. Boxplots of covariate values vs. ignitions for Dataset A (3rd part of 6)

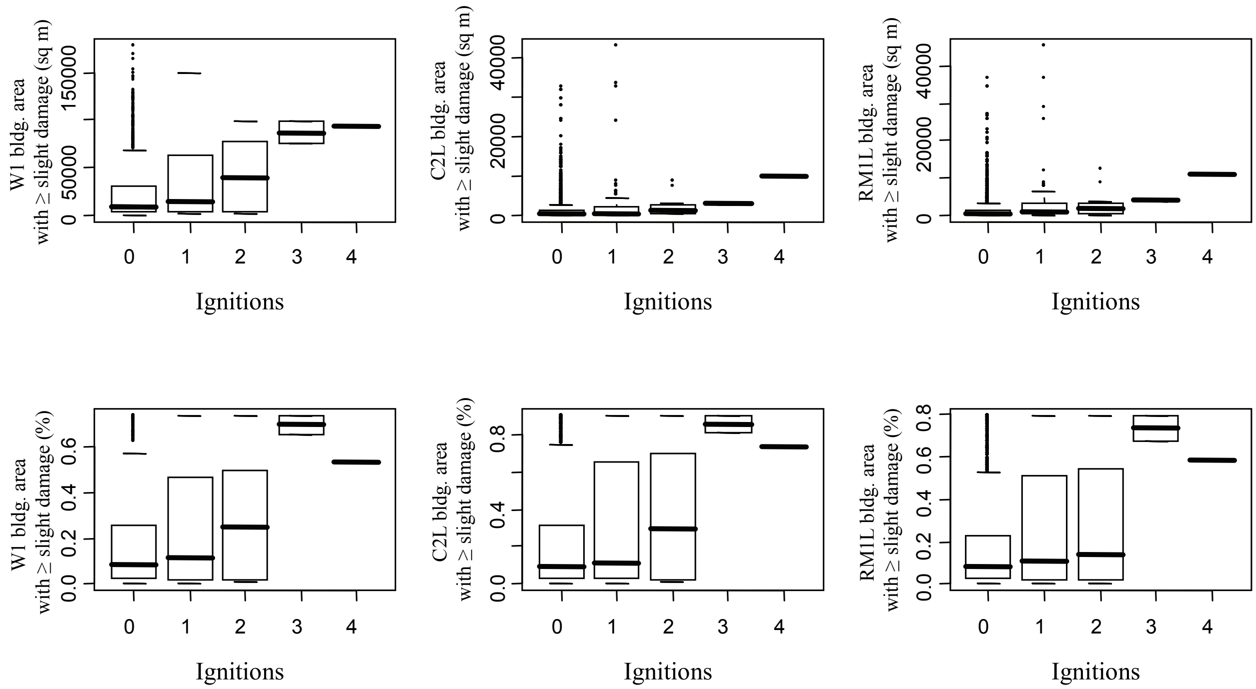


Figure B.3. Boxplots of covariate values vs. ignitions for Dataset A (4th part of 6)

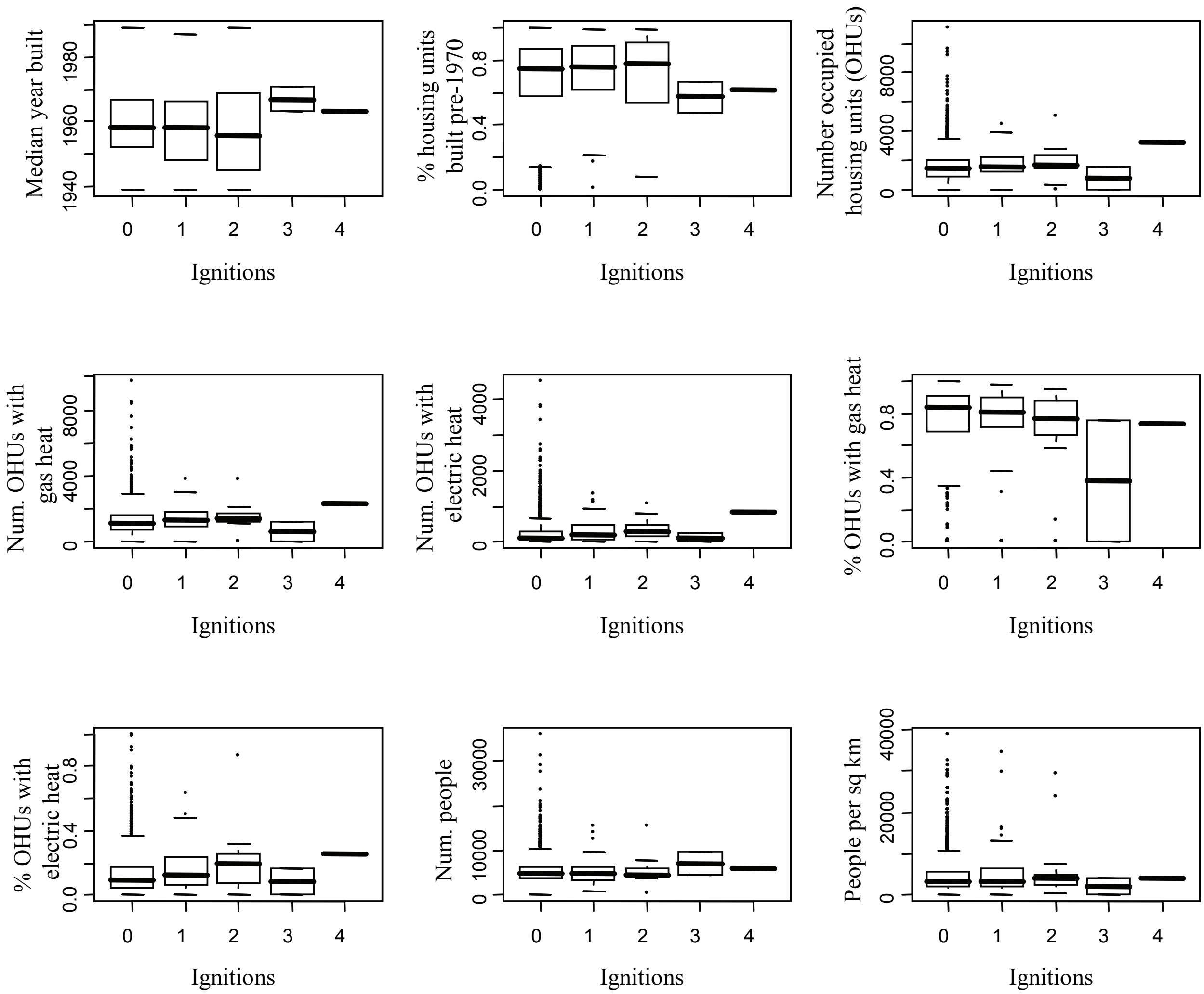


Figure B.3. Boxplots of covariate values vs. ignitions for Dataset A (5th part of 6)

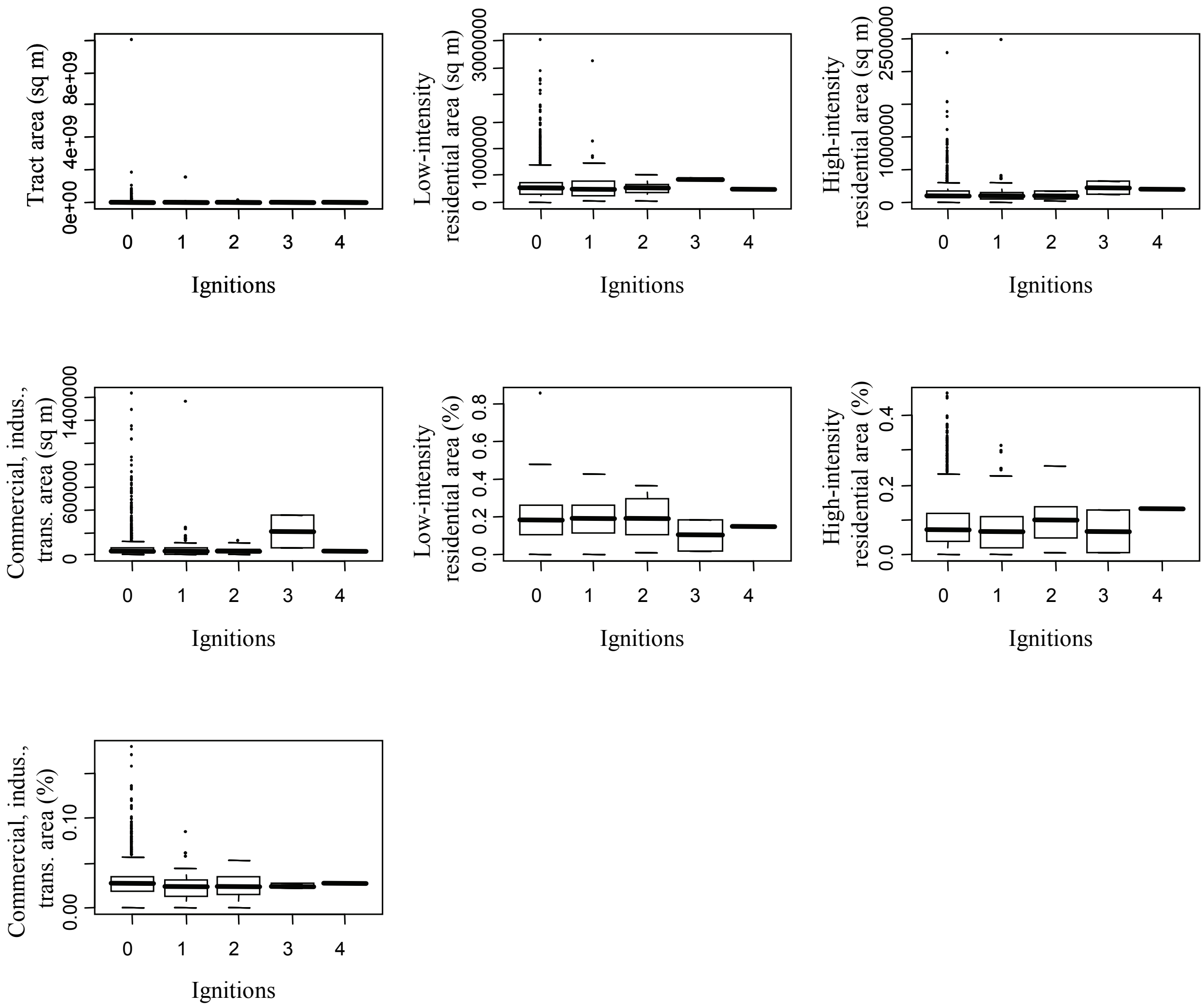


Figure B.3. Boxplots of covariate values vs. ignitions for Dataset A (6th part of 6)

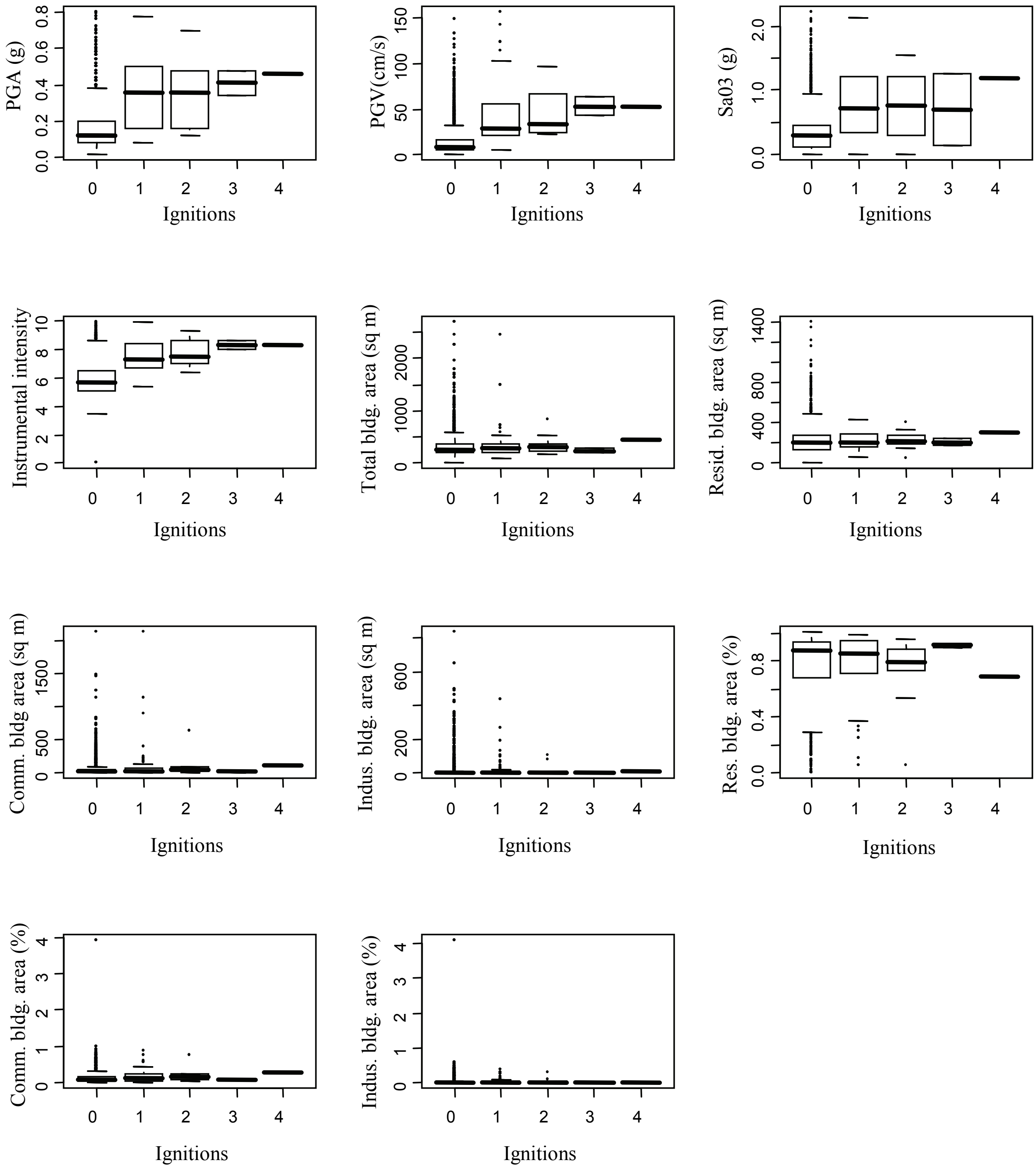


Figure B.4. Boxplots of covariate values vs. ignitions for Dataset B (1st part of 6)

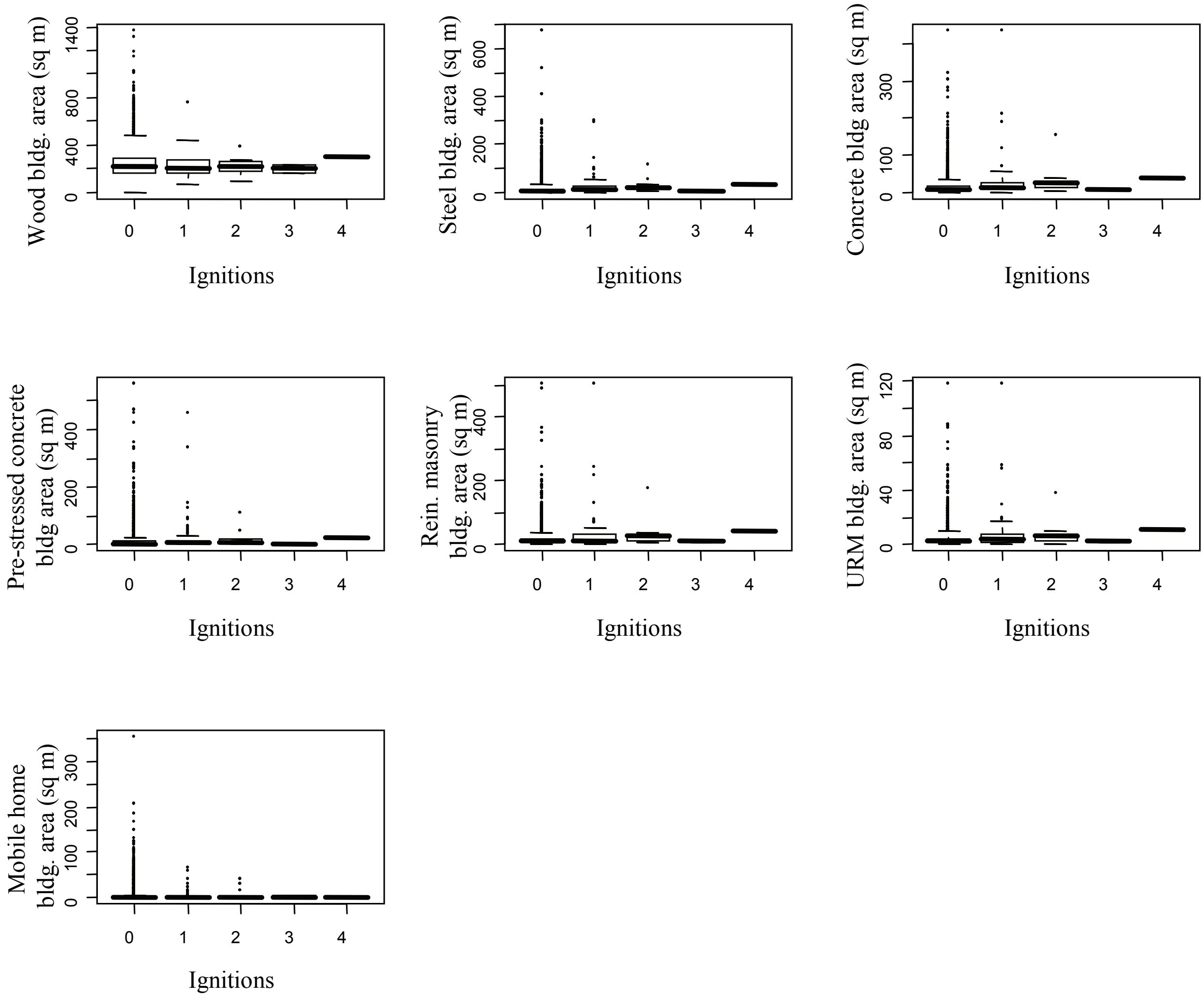


Figure B.4. Boxplots of covariate values vs. ignitions for Dataset B (2nd part of 6)

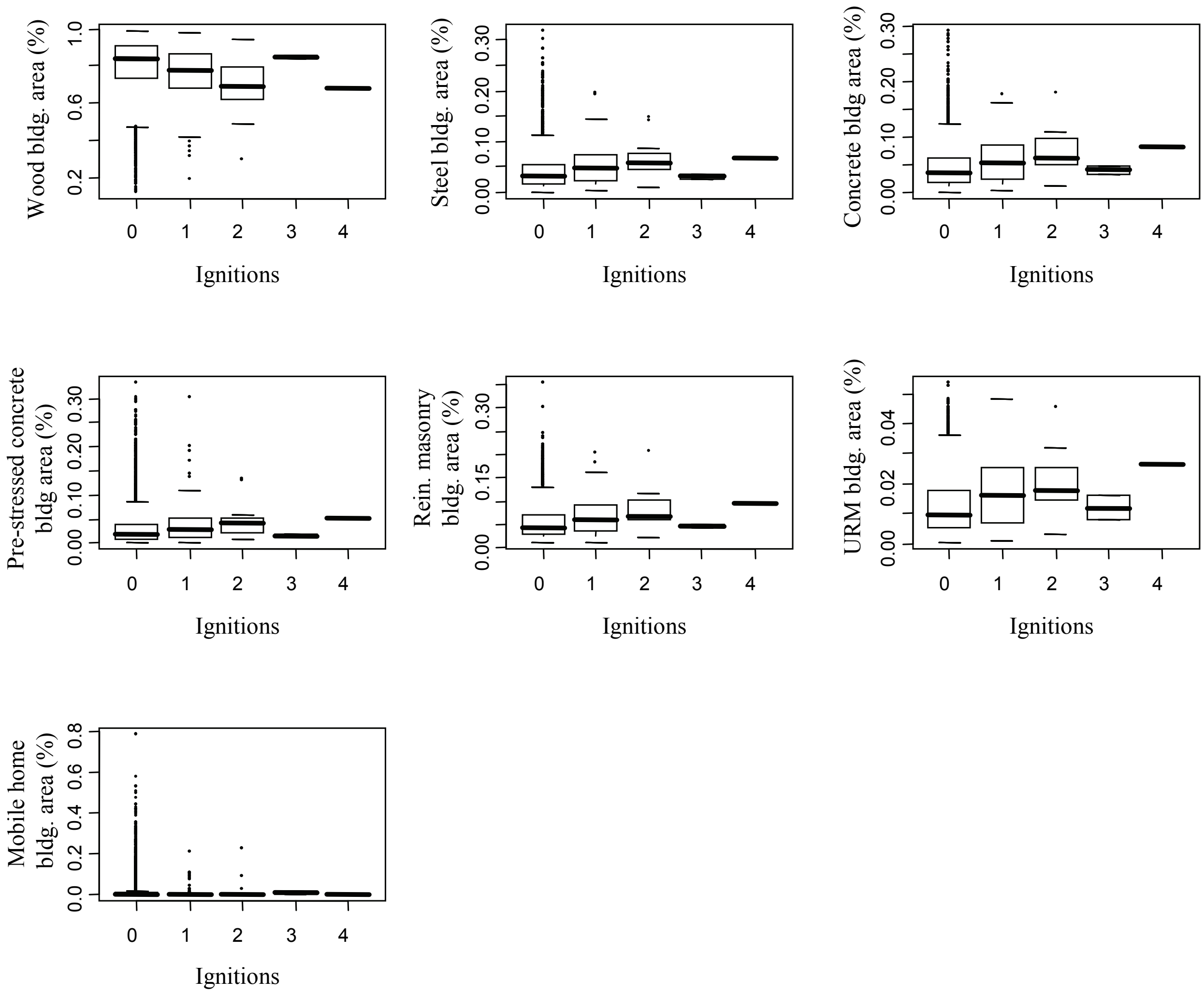


Figure B.4. Boxplots of covariate values vs. ignitions for Dataset B (3rd part of 6)

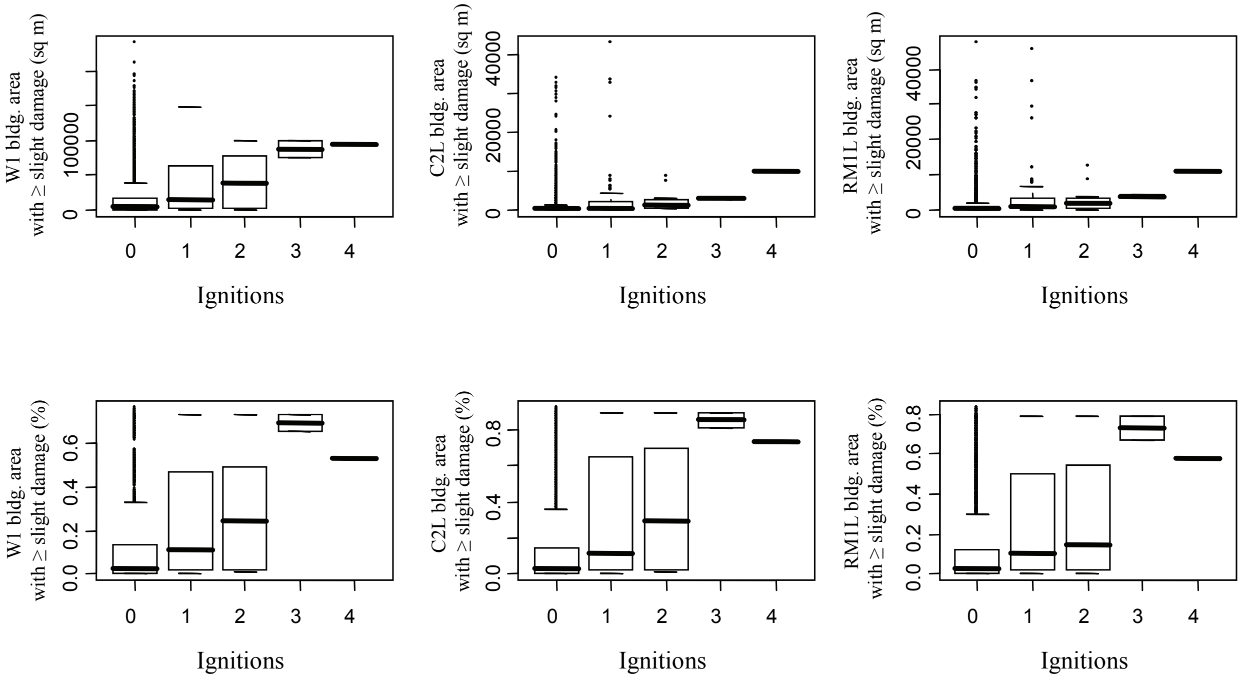


Figure B.4. Boxplots of covariate values vs. ignitions for Dataset B (4th part of 6)

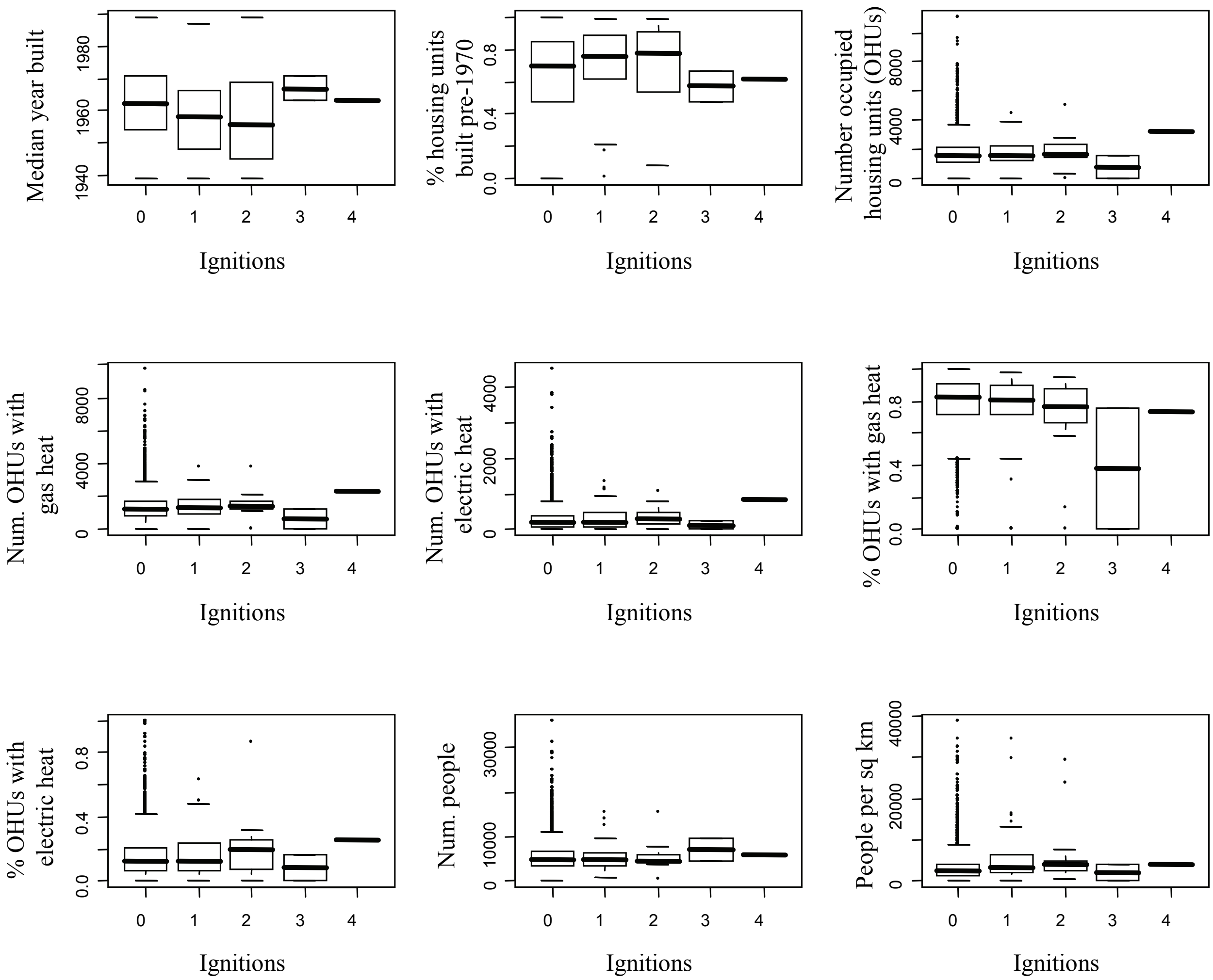


Figure B.4. Boxplots of covariate values vs. ignitions for Dataset B (5th part of 6)

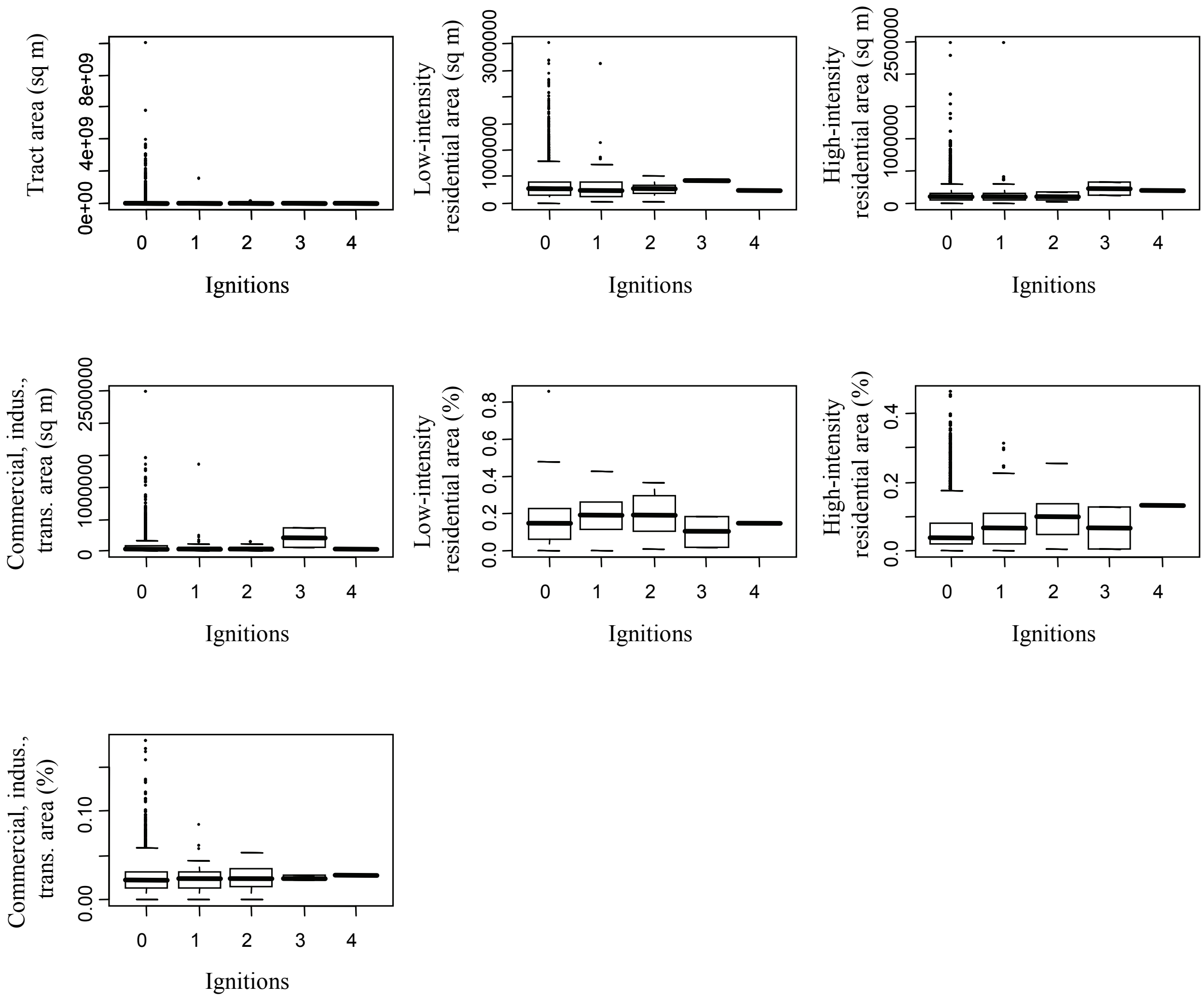


Figure B.4. Boxplots of covariate values vs. ignitions for Dataset B (6th part of 6)

Table B-1. Correlation matrix for Dataset A (1st half)

	y	*xpga*	*xpgv*	*xsa*	*xii*	*tbldg*	*xrbldg*	*xcbldg*	*xibldg*	*x%rbldg*	*x%cbldg*	*x%ibldg*	*xwood*	*xsteel*	*xcon*	*xprecon*	*xRM*	*xURM*	*xMH*	*x%wood*	*x%steel*	*x%con*	*x%precon*	*x%RM*
y	1.00	0.22	0.29	0.21	0.25	0.07	0.02	0.07	0.02	-0.06	0.06	0.01	0.04	0.06	0.08	0.05	0.07	0.08	0.00	-0.05	0.04	0.05	0.03	0.06
xpga	0.22	1.00	0.84	0.92	0.87	-0.10	-0.13	-0.03	-0.03	0.00	0.01	0.01	-0.12	-0.03	-0.03	-0.03	-0.04	-0.03	-0.08	0.00	0.01	0.02	0.02	0.01
xpgv	0.29	0.84	1.00	0.87	0.92	-0.06	-0.08	-0.01	-0.02	-0.02	0.02	0.01	-0.08	-0.01	0.00	-0.01	-0.01	0.00	-0.06	-0.02	0.03	0.04	0.03	0.03
xsa	0.21	0.92	0.87	1.00	0.88	-0.09	-0.11	-0.03	-0.02	0.00	0.00	0.02	-0.11	-0.03	-0.04	-0.02	-0.04	-0.03	-0.07	0.01	0.01	0.00	0.02	0.00
xii	0.25	0.87	0.92	0.88	1.00	-0.10	-0.15	-0.01	-0.03	-0.02	0.03	0.01	-0.15	-0.02	0.00	-0.02	-0.02	0.00	-0.09	-0.04	0.05	0.07	0.04	0.06
tbldg	0.07	-0.10	-0.06	-0.09	-0.10	1.00	0.59	0.81	0.59	-0.48	0.48	0.33	0.75	0.79	0.82	0.75	0.83	0.82	0.13	-0.37	0.36	0.27	0.43	0.34
xrbldg	0.02	-0.13	-0.08	-0.11	-0.15	0.59	1.00	0.05	-0.02	0.20	-0.17	-0.17	0.95	0.04	0.08	0.00	0.11	0.08	0.13	0.25	-0.26	-0.26	-0.22	-0.24
xcbldg	0.07	-0.03	-0.01	-0.03	-0.01	0.81	0.05	1.00	0.58	-0.69	0.73	0.37	0.29	0.87	0.95	0.85	0.97	0.96	0.04	-0.58	0.55	0.51	0.60	0.58
xibldg	0.02	-0.03	-0.02	-0.02	-0.03	0.59	-0.02	0.58	1.00	-0.59	0.43	0.80	0.12	0.83	0.61	0.87	0.60	0.63	0.14	-0.53	0.61	0.31	0.70	0.35
x%rbldg	-0.06	0.00	-0.02	0.00	-0.02	-0.48	0.20	-0.69	-0.59	1.00	-0.93	-0.69	0.03	-0.72	-0.70	-0.71	-0.69	-0.69	-0.04	0.89	-0.90	-0.76	-0.91	-0.85
x%cbldg	0.06	0.01	0.02	0.00	0.03	0.48	-0.17	0.73	0.43	-0.93	1.00	0.47	0.01	0.66	0.71	0.65	0.71	0.72	0.01	-0.83	0.78	0.76	0.81	0.85
x%ibldg	0.01	0.01	0.01	0.02	0.01	0.33	-0.17	0.37	0.80	-0.69	0.47	1.00	-0.06	0.61	0.39	0.64	0.38	0.41	0.12	-0.64	0.75	0.37	0.84	0.41
xwood	0.04	-0.12	-0.08	-0.11	-0.15	0.75	0.95	0.29	0.12	0.03	0.01	-0.06	1.00	0.22	0.28	0.21	0.31	0.29	0.04	0.18	-0.17	-0.20	-0.08	-0.15
xsteel	0.06	-0.03	-0.01	-0.03	-0.02	0.79	0.04	0.87	0.83	-0.72	0.66	0.61	0.22	1.00	0.90	0.91	0.92	0.91	0.08	-0.67	0.72	0.55	0.69	0.61
xcon	0.08	-0.03	0.00	-0.04	0.00	0.82	0.08	0.95	0.61	-0.70	0.71	0.39	0.28	0.90	1.00	0.84	0.99	0.98	0.03	-0.67	0.64	0.65	0.60	0.69
xprecon	0.05	-0.03	-0.01	-0.02	-0.02	0.75	0.00	0.85	0.87	-0.71	0.65	0.64	0.21	0.91	0.84	1.00	0.83	0.86	0.10	-0.63	0.63	0.46	0.77	0.51
xRM	0.07	-0.04	-0.01	-0.04	-0.02	0.83	0.11	0.97	0.60	-0.69	0.71	0.38	0.31	0.92	0.99	0.83	1.00	0.98	0.04	-0.64	0.62	0.59	0.58	0.66
xURM	0.08	-0.03	0.00	-0.03	0.00	0.82	0.08	0.96	0.63	-0.69	0.72	0.41	0.29	0.91	0.98	0.86	0.98	1.00	0.03	-0.65	0.62	0.60	0.62	0.65
xMH	0.00	-0.08	-0.06	-0.07	-0.09	0.13	0.13	0.04	0.14	-0.04	0.01	0.12	0.04	0.08	0.03	0.10	0.04	0.03	1.00	-0.24	0.03	-0.05	0.07	-0.05
x%wood	-0.05	0.00	-0.02	0.01	-0.04	-0.37	0.25	-0.58	-0.53	0.89	-0.83	-0.64	0.18	-0.67	-0.67	-0.63	-0.64	-0.65	-0.24	1.00	-0.94	-0.88	-0.84	-0.91
x%steel	0.04	0.01	0.03	0.01	0.05	0.36	-0.26	0.55	0.61	-0.90	0.78	0.75	-0.17	0.72	0.64	0.63	0.62	0.62	0.03	-0.94	1.00	0.86	0.86	0.89
x%con	0.05	0.02	0.04	0.00	0.07	0.27	-0.26	0.51	0.31	-0.76	0.76	0.37	-0.20	0.55	0.65	0.46	0.59	0.60	-0.05	-0.88	0.86	1.00	0.63	0.97
x%precon	0.03	0.02	0.03	0.02	0.04	0.43	-0.22	0.60	0.70	-0.91	0.81	0.84	-0.08	0.69	0.60	0.77	0.58	0.62	0.07	-0.84	0.86	0.63	1.00	0.70
x%RM	0.06	0.01	0.03	0.00	0.06	0.34	-0.24	0.58	0.35	-0.85	0.85	0.41	-0.15	0.61	0.69	0.51	0.66	0.65	-0.05	-0.91	0.89	0.97	0.70	1.00
x%URM	0.07	0.04	0.06	0.02	0.10	0.28	-0.26	0.53	0.35	-0.76	0.79	0.41	-0.19	0.56	0.63	0.50	0.58	0.66	-0.07	-0.85	0.82	0.89	0.69	0.88
x%MH	0.00	-0.08	-0.06	-0.07	-0.08	0.00	0.02	-0.03	0.03	0.03	-0.04	0.04	-0.08	-0.01	-0.04	0.00	-0.04	-0.05	0.92	-0.21	-0.04	-0.09	-0.01	-0.09
xW1	0.11	0.39	0.26	0.35	0.24	0.13	0.21	0.02	-0.02	0.04	-0.02	-0.05	0.23	0.00	0.02	-0.01	0.02	0.02	-0.08	0.10	-0.08	-0.09	-0.05	-0.07
xC2L	0.09	0.20	0.12	0.17	0.12	0.43	0.06	0.51	0.27	-0.44	0.46	0.21	0.16	0.45	0.54	0.43	0.53	0.52	-0.02	-0.41	0.39	0.41	0.37	0.44
xRM1L	0.10	0.23	0.15	0.20	0.14	0.43	0.09	0.49	0.23	-0.41	0.44	0.18	0.20	0.42	0.50	0.39	0.49	0.49	-0.03	-0.35	0.33	0.34	0.33	0.39
x%W1	0.10	0.45	0.29	0.40	0.28	-0.02	-0.04	0.01	-0.02	-0.02	0.04	0.00	-0.03	-0.01	0.01	0.00	0.00	0.01	-0.09	0.01	0.01	0.01	0.02	0.02
x%C2L	0.10	0.45	0.29	0.41	0.28	-0.02	-0.04	0.01	-0.02	-0.02	0.04	-0.01	-0.02	0.00	0.01	0.00	0.01	0.01	-0.09	0.00	0.01	0.01	0.02	0.02
x%RM1L	0.11	0.44	0.30	0.40	0.28	-0.01	-0.03	0.01	-0.02	-0.02	0.04	-0.01	-0.02	-0.01	0.01	0.00	0.01	0.01	-0.09	0.01	0.00	0.00	0.02	0.01
xyrblt	-0.02	-0.11	-0.10	-0.07	-0.21	0.17	0.21	0.04	0.11	-0.05	0.02	0.10	0.19	0.08	0.04	0.08	0.05	0.04	0.28	-0.07	0.03	-0.04	0.05	-0.02
x%pre70	0.01	0.14	0.10	0.11	0.18	-0.20	-0.21	-0.09	-0.11	0.08	-0.07	-0.08	-0.19	-0.11	-0.11	-0.11	-0.11	-0.10	-0.27	0.13	-0.07	-0.05	-0.07	-0.06
xOHU	0.05	-0.09	-0.04	-0.09	-0.07	0.35	0.59	0.04	-0.03	0.09	-0.05	-0.12	0.52	0.05	0.10	0.00	0.10	0.12	0.17	0.05	-0.09	-0.05	-0.12	-0.05
xgas	0.03	-0.09	-0.05	-0.08	-0.08	0.32	0.60	0.00	-0.04	0.14	-0.12	-0.13	0.54	0.00	0.02	-0.03	0.04	0.04	0.18	0.13	-0.16	-0.16	-0.16	-0.15
xelec	0.05	-0.06	0.00	-0.07	-0.02	0.27	0.33	0.13	0.00	-0.07	0.12	-0.05	0.28	0.14	0.22	0.07	0.20	0.24	0.06	-0.15	0.12	0.21	0.02	0.19
x%gas	0.00	-0.05	-0.01	-0.04	-0.04	0.08	0.21	-0.05	-0.01	0.12	-0.11	-0.07	0.21	-0.05	-0.08	-0.04	-0.06	-0.09	0.04	0.19	-0.19	-0.24	-0.13	-0.20
x%elec	0.06	-0.07	0.02	-0.08	0.00	0.21	0.10	0.20	0.06	-0.20	0.23	0.03	0.09	0.20	0.29	0.14	0.26	0.29	0.00	-0.27	0.24	0.33	0.13	0.32
xpop	0.00	-0.05	-0.08	-0.04	-0.08	0.12	0.34	-0.09	-0.05	0.18	-0.18	-0.08	0.27	-0.06	-0.06	-0.07	-0.06	-0.05	0.14	0.11	-0.13	-0.12	-0.13	-0.15
xdens	0.04	0.05	0.06	0.03	0.14	-0.23	-0.23	-0.10	-0.15	0.09	-0.04	-0.18	-0.30	-0.08	-0.01	-0.13	-0.05	0.01	-0.17	-0.08	0.08	0.26	-0.10	0.18
xarea	0.00	-0.01	-0.01	-0.03	-0.02	0.01	0.04	-0.01	-0.01	0.02	-0.02	-0.01	0.01	-0.01	0.00	-0.01	-0.01	-0.02	0.19	-0.04	-0.02	0.00	-0.02	-0.01
xlowres	0.00	0.01	0.01	0.02	-0.02	0.31	0.26	0.16	0.29	-0.11	0.06	0.23	0.30	0.22	0.12	0.26	0.14	0.13	0.16	-0.04	0.06	-0.10	0.17	-0.06
xhires	0.00	-0.03	-0.08	-0.02	-0.08	0.38	0.08	0.35	0.46	-0.38	0.33	0.41	0.14	0.44	0.36	0.49	0.35	0.37	0.14	-0.38	0.38	0.25	0.45	0.28
xCIT	0.00	-0.07	-0.06	-0.06	-0.09	0.35	0.14	0.27	0.41	-0.28	0.20	0.37	0.20	0.35	0.25	0.39	0.26	0.25	0.20	-0.26	0.26	0.11	0.33	0.14
x%lowres	0.00	0.12	0.11	0.11	0.17	-0.17	-0.18	-0.07	-0.07	0.08	-0.06	-0.07	-0.19	-0.07	-0.07	-0.06	-0.07	-0.04	-0.19	0.09	-0.05	-0.03	-0.05	-0.04
x%hires	-0.01	0.09	-0.02	0.08	0.06	-0.09	-0.32	0.12	0.04	-0.24	0.27	0.08	-0.32	0.13	0.19	0.11	0.15	0.20	-0.12	-0.35	0.33	0.44	0.23	0.40
x%CIT	-0.05	0.04	0.03	0.07	0.05	0.01	-0.28	0.19	0.23	-0.33	0.30	0.33	-0.23	0.23	0.20	0.24	0.18	0.21	-0.08	-0.34	0.37	0.30	0.37	0.30

* Variables are defined in Table 2-1.

Table B-1. Correlation matrix for Dataset A (2nd half)

	x%URM	x%MH	xW1	xC2L	xRM1L	x%W1	x%C2L	x%RM1L	xyrblt	x%pre70	xOHU	xgas	xelec	x%gas	x%elec	xpop	xdens	xarea	xlowres	xhires	xCIT	x%lowres	x%hires	x%CIT
y	0.07	0.00	0.11	0.09	0.10	0.10	0.10	0.11	-0.02	0.01	0.05	0.03	0.05	0.00	0.06	0.00	0.04	0.00	0.00	0.00	0.00	0.00	-0.01	-0.05
xpga	0.04	-0.08	0.39	0.20	0.23	0.45	0.45	0.44	-0.11	0.14	-0.09	-0.09	-0.06	-0.05	-0.07	-0.05	0.05	-0.01	0.01	-0.03	-0.07	0.12	0.09	0.04
xpgv	0.06	-0.06	0.26	0.12	0.15	0.29	0.29	0.30	-0.10	0.10	-0.04	-0.05	0.00	-0.01	0.02	-0.08	0.06	-0.01	0.01	-0.08	-0.06	0.11	-0.02	0.03
xsa	0.02	-0.07	0.35	0.17	0.20	0.40	0.41	0.40	-0.07	0.11	-0.09	-0.08	-0.07	-0.04	-0.08	-0.04	0.03	-0.03	0.02	-0.02	-0.06	0.11	0.08	0.07
xii	0.10	-0.08	0.24	0.12	0.14	0.28	0.28	0.28	-0.21	0.18	-0.07	-0.08	-0.02	-0.04	0.00	-0.08	0.14	-0.02	-0.02	-0.08	-0.09	0.17	0.06	0.05
tbldg	0.28	0.00	0.13	0.43	0.43	-0.02	-0.02	-0.01	0.17	-0.20	0.35	0.32	0.27	0.08	0.21	0.12	-0.23	0.01	0.31	0.38	0.35	-0.17	-0.09	0.01
xrbldg	-0.26	0.02	0.21	0.06	0.09	-0.04	-0.04	-0.03	0.21	-0.21	0.59	0.60	0.33	0.21	0.10	0.34	-0.23	0.04	0.26	0.08	0.14	-0.18	-0.32	-0.28
xcbldg	0.53	-0.03	0.02	0.51	0.49	0.01	0.01	0.01	0.04	-0.09	0.04	0.00	0.13	-0.05	0.20	-0.09	-0.10	-0.01	0.16	0.35	0.27	-0.07	0.12	0.19
xibldg	0.35	0.03	-0.02	0.27	0.23	-0.02	-0.02	-0.02	0.11	-0.11	-0.03	-0.04	0.00	-0.01	0.06	-0.05	-0.15	-0.01	0.29	0.46	0.41	-0.07	0.04	0.23
x%rbldg	-0.76	0.03	0.04	-0.44	-0.41	-0.02	-0.02	-0.02	-0.05	0.08	0.09	0.14	-0.07	0.12	-0.20	0.18	0.09	0.02	-0.11	-0.38	-0.28	0.08	-0.24	-0.33
x%cbldg	0.79	-0.04	-0.02	0.46	0.44	0.04	0.04	0.04	0.02	-0.07	-0.05	-0.12	0.12	-0.11	0.23	-0.18	-0.04	-0.02	0.06	0.33	0.20	-0.06	0.27	0.30
x%ibldg	0.41	0.04	-0.05	0.21	0.18	0.00	-0.01	-0.01	0.10	-0.08	-0.12	-0.13	-0.05	-0.07	0.03	-0.08	-0.18	-0.01	0.23	0.41	0.37	-0.07	0.08	0.33
xwood	-0.19	-0.08	0.23	0.16	0.20	-0.03	-0.02	-0.02	0.19	-0.19	0.52	0.54	0.28	0.21	0.09	0.27	-0.30	0.01	0.30	0.14	0.20	-0.19	-0.32	-0.23
xsteel	0.56	-0.01	0.00	0.45	0.42	-0.01	0.00	-0.01	0.08	-0.11	0.05	0.00	0.14	-0.05	0.20	-0.06	-0.08	-0.01	0.22	0.44	0.35	-0.07	0.13	0.23
xcon	0.63	-0.04	0.02	0.54	0.50	0.01	0.01	0.01	0.04	-0.11	0.10	0.02	0.22	-0.08	0.29	-0.06	-0.01	0.00	0.12	0.36	0.25	-0.07	0.19	0.20
xprecon	0.50	0.00	-0.01	0.43	0.39	0.00	0.00	0.00	0.08	-0.11	0.00	-0.03	0.07	-0.04	0.14	-0.07	-0.13	-0.01	0.26	0.49	0.39	-0.06	0.11	0.24
xRM	0.58	-0.04	0.02	0.53	0.49	0.00	0.01	0.01	0.05	-0.11	0.10	0.04	0.20	-0.06	0.26	-0.06	-0.05	-0.01	0.14	0.35	0.26	-0.07	0.15	0.18
xURM	0.66	-0.05	0.02	0.52	0.49	0.01	0.01	0.01	0.04	-0.10	0.12	0.04	0.24	-0.09	0.29	-0.05	0.01	-0.02	0.13	0.37	0.25	-0.04	0.20	0.21
xMH	-0.07	0.92	-0.08	-0.02	-0.03	-0.09	-0.09	-0.09	0.28	-0.27	0.17	0.18	0.06	0.04	0.00	0.14	-0.17	0.19	0.16	0.14	0.20	-0.19	-0.12	-0.08
x%wood	-0.85	-0.21	0.10	-0.41	-0.35	0.01	0.00	0.01	-0.07	0.13	0.05	0.13	-0.15	0.19	-0.27	0.11	-0.08	-0.04	-0.04	-0.38	-0.26	0.09	-0.35	-0.34
x%steel	0.82	-0.04	-0.08	0.39	0.33	0.01	0.01	0.00	0.03	-0.07	-0.09	-0.16	0.12	-0.19	0.24	-0.13	0.08	-0.02	0.06	0.38	0.26	-0.05	0.33	0.37
x%con	0.89	-0.09	-0.09	0.41	0.34	0.01	0.01	0.00	-0.04	-0.05	-0.05	-0.16	0.21	-0.24	0.33	-0.12	0.26	0.00	-0.10	0.25	0.11	-0.03	0.44	0.30
x%precon	0.69	-0.01	-0.05	0.37	0.33	0.02	0.02	0.02	0.05	-0.07	-0.12	-0.16	0.02	-0.13	0.13	-0.13	-0.10	-0.02	0.17	0.45	0.33	-0.05	0.23	0.37
x%RM	0.88	-0.09	-0.07	0.44	0.39	0.02	0.02	0.01	-0.02	-0.06	-0.05	-0.15	0.19	-0.20	0.32	-0.15	0.18	-0.01	-0.06	0.28	0.14	-0.04	0.40	0.30
x%URM	1.00	-0.11	-0.07	0.40	0.35	0.03	0.03	0.02	-0.04	-0.06	0.00	-0.13	0.28	-0.28	0.37	-0.08	0.37	-0.04	-0.11	0.25	0.08	0.04	0.52	0.34
x%MH	-0.11	1.00	-0.09	-0.06	-0.06	-0.08	-0.08	-0.08	0.25	-0.24	0.12	0.13	0.02	0.04	-0.02	0.11	-0.14	0.19	0.09	0.07	0.14	-0.16	-0.10	-0.07
xW1	-0.07	-0.09	1.00	0.49	0.59	0.91	0.90	0.90	-0.01	0.07	0.12	0.13	0.05	0.10	-0.02	0.00	-0.11	-0.03	0.09	-0.02	-0.02	0.03	-0.07	-0.03
xC2L	0.40	-0.06	0.49	1.00	0.98	0.52	0.52	0.52	0.02	-0.02	0.07	0.03	0.16	-0.05	0.15	-0.03	-0.03	-0.02	0.08	0.23	0.14	-0.01	0.14	0.17
xRM1L	0.35	-0.06	0.59	0.98	1.00	0.59	0.60	0.60	0.02	-0.01	0.08	0.05	0.14	-0.02	0.13	-0.04	-0.07	-0.02	0.09	0.19	0.12	-0.01	0.10	0.15
x%W1	0.03	-0.08	0.91	0.52	0.59	1.00	1.00	0.99	-0.03	0.09	-0.04	-0.04	-0.03	-0.01	-0.05	-0.04	-0.01	-0.03	0.01	-0.02	-0.04	0.09	0.06	0.05
x%C2L	0.03	-0.08	0.90	0.52	0.60	1.00	1.00	1.00	-0.03	0.09	-0.04	-0.04	-0.02	0.00	-0.05	-0.05	-0.02	-0.03	0.02	-0.02	-0.04	0.08	0.05	0.05
x%RM1L	0.02	-0.08	0.90	0.52	0.60	0.99	1.00	1.00	-0.01	0.08	-0.04	-0.03	-0.02	0.00	-0.04	-0.05	-0.03	-0.02	0.01	-0.03	-0.04	0.08	0.04	0.05
xyrblt	-0.04	0.25	-0.01	0.02	0.02	-0.03	-0.03	-0.01	1.00	-0.87	0.13	0.08	0.22	-0.13	0.19	0.25	-0.26	0.06	0.15	0.20	0.25	-0.41	-0.11	-0.01
x%pre70	-0.06	-0.24	0.07	-0.02	-0.01	0.09	0.09	0.08	-0.87	1.00	-0.16	-0.09	-0.27	0.18	-0.26	-0.27	0.17	-0.07	-0.08	-0.18	-0.24	0.44	0.08	0.03
xOHU	0.00	0.12	0.12	0.07	0.08	-0.04	-0.04	-0.04	0.13	-0.16	1.00	0.95	0.68	0.49	0.43	0.28	-0.02	-0.01	0.19	0.05	0.06	-0.06	-0.13	-0.17
xgas	-0.13	0.13	0.13	0.03	0.05	-0.04	-0.04	-0.03	0.08	-0.09	0.95	1.00	0.42	0.60	0.19	0.28	-0.10	-0.01	0.24	0.04	0.07	-0.03	-0.19	-0.20
xelec	0.28	0.02	0.05	0.16	0.14	-0.03	-0.02	-0.02	0.22	-0.27	0.68	0.42	1.00	0.01	0.80	0.17	0.12	0.01	0.02	0.05	0.04	-0.10	0.05	-0.03
x%gas	-0.28	0.04	0.10	-0.05	-0.02	-0.01	0.00	0.00	-0.13	0.18	0.49	0.60	0.01	1.00	0.05	-0.40	-0.25	-0.02	-0.04	-0.21	-0.12	0.07	-0.26	-0.15
x%elec	0.37	-0.02	-0.02	0.15	0.13	-0.05	-0.05	-0.04	0.19	-0.26	0.43	0.19	0.80	0.05	1.00	-0.15	0.10	0.03	-0.16	-0.04	-0.01	-0.12	0.07	0.05
xpop	-0.08	0.11	0.00	-0.03	-0.04	-0.04	-0.05	-0.05	0.25	-0.27	0.28	0.28	0.17	-0.40	-0.15	1.00	0.14	0.01	0.43	0.28	0.21	-0.07	0.02	-0.07
xdens	0.37	-0.14	-0.11	-0.03	-0.07	-0.01	-0.02	-0.03	-0.26	0.17	-0.02	-0.10	0.12	-0.25	0.10	0.14	1.00	-0.06	-0.35	-0.20	-0.32	0.24	0.60	0.08
xarea	-0.04	0.19	-0.03	-0.02	-0.02	-0.03	-0.03	-0.02	0.06	-0.07	-0.01	-0.01	0.01	-0.02	0.03	0.01	-0.06	1.00	0.01	0.03	0.28	-0.09	-0.06	-0.08
xlowres	-0.11	0.09	0.09	0.08	0.09	0.01	0.02	0.01	0.15	-0.08	0.19	0.24	0.02	-0.04	-0.16	0.43	-0.35	0.01	1.00	0.67	0.61	0.17	-0.21	0.01
xhires	0.25	0.07	-0.02	0.23	0.19	-0.02	-0.02	-0.03	0.20	-0.18	0.05	0.04	0.05	-0.21	-0.04	0.28	-0.20	0.03	0.67	1.00	0.80	-0.14	0.21	0.33
xCIT	0.08	0.14	-0.02	0.14	0.12	-0.04	-0.04	-0.04	0.25	-0.24	0.06	0.07	0.04	-0.12	-0.01	0.21	-0.32	0.28	0.61	0.80	1.00	-0.29	-0.13	0.26
x%lowres	0.04	-0.16	0.03	-0.01	-0.01	0.09	0.08	0.08	-0.41	0.44	-0.06	-0.03	-0.10	0.07	-0.12	-0.07	0.24	-0.09	0.17	-0.14	-0.29	1.00	0.11	-0.04
x%hires	0.52	-0.10	-0.07	0.14	0.10	0.06	0.05	0.04	-0.11	0.08	-0.13	-0.19	0.05	-0.26	0.07	0.02	0.60	-0.06	-0.21	0.21	-0.13	0.11	1.00	0.34
x%CIT	0.34	-0.07	-0.03	0.17	0.15	0.05	0.05	0.05	-0.01	0.03	-0.17	-0.20	-0.03	-0.15	0.05	-0.07	0.08	-0.08	0.01	0.33	0.26	-0.04	0.34	1.00

* Variables are defined in Table 2-1.

Table B-2. Correlation matrix for Dataset B (1st half)

	y	*xpga*	*xpgv*	*xsa*	*xii*	*tbldg*	*xrbldg*	*xcbldg*	*xibldg*	*x%rbldg*	*x%cbldg*	*x%ibldg*	*xwood*	*xsteel*	*xcon*	*xprecon*	*xRM*	*xURM*	*xMH*	*x%wood*	*x%steel*	*x%con*	*x%precon*	*x%RM*
y	1.00	0.20	0.23	0.18	0.18	0.02	0.02	0.06	0.02	0.02	0.05	0.01	-0.01	0.03	0.06	0.03	0.05	0.06	-0.01	-0.04	0.04	0.05	0.03	0.05
xpga	0.20	1.00	0.87	0.92	0.89	-0.08	-0.05	0.00	0.00	0.05	0.04	0.03	-0.10	-0.01	-0.01	-0.01	-0.01	0.00	-0.09	-0.01	0.03	0.04	0.03	0.03
xpgv	0.23	0.87	1.00	0.83	0.89	-0.04	-0.04	0.00	0.00	0.02	0.03	0.02	-0.06	0.00	0.01	0.00	0.00	0.01	-0.06	-0.01	0.03	0.03	0.03	0.03
xsa	0.18	0.92	0.83	1.00	0.86	-0.08	-0.04	0.01	0.01	0.06	0.05	0.04	-0.11	0.00	0.00	0.00	-0.01	0.01	-0.08	-0.02	0.04	0.04	0.05	0.04
xii	0.18	0.89	0.89	0.86	1.00	-0.06	-0.05	0.01	0.01	0.03	0.05	0.04	-0.10	0.01	0.01	0.01	0.01	0.02	-0.10	-0.02	0.05	0.05	0.05	0.05
tbldg	0.02	-0.08	-0.04	-0.08	-0.06	1.00	0.47	0.65	0.49	-0.23	0.30	0.22	0.79	0.74	0.75	0.72	0.78	0.76	0.17	-0.29	0.32	0.19	0.39	0.25
xrbldg	0.02	-0.05	-0.04	-0.04	-0.05	0.47	1.00	0.14	0.06	0.60	0.04	-0.02	0.66	0.04	0.08	0.01	0.10	0.08	0.06	0.17	-0.16	-0.15	-0.14	-0.14
xcbldg	0.06	0.00	0.00	0.01	0.01	0.65	0.14	1.00	0.60	-0.20	0.72	0.40	0.20	0.74	0.86	0.73	0.88	0.88	0.05	-0.55	0.54	0.48	0.58	0.56
xibldg	0.02	0.00	0.00	0.01	0.01	0.49	0.06	0.60	1.00	-0.21	0.48	0.77	0.09	0.70	0.56	0.76	0.56	0.59	0.11	-0.50	0.58	0.31	0.66	0.35
x%rbldg	0.02	0.05	0.02	0.06	0.03	-0.23	0.60	-0.20	-0.21	1.00	-0.17	-0.18	-0.03	-0.31	-0.30	-0.32	-0.31	-0.30	-0.12	0.39	-0.38	-0.29	-0.40	-0.33
x%cbldg	0.05	0.04	0.03	0.05	0.05	0.30	0.04	0.72	0.48	-0.17	1.00	0.58	-0.08	0.50	0.59	0.49	0.58	0.60	-0.01	-0.72	0.69	0.67	0.71	0.75
x%ibldg	0.01	0.03	0.02	0.04	0.04	0.22	-0.02	0.40	0.77	-0.18	0.58	1.00	-0.06	0.44	0.32	0.46	0.31	0.34	0.07	-0.49	0.58	0.30	0.62	0.34
xwood	-0.01	-0.10	-0.06	-0.11	-0.10	0.79	0.66	0.20	0.09	-0.03	-0.08	-0.06	1.00	0.20	0.23	0.18	0.27	0.23	0.06	0.22	-0.18	-0.24	-0.10	-0.20
xsteel	0.03	-0.01	0.00	0.00	0.01	0.74	0.04	0.74	0.70	-0.31	0.50	0.44	0.20	1.00	0.90	0.93	0.92	0.91	0.08	-0.64	0.70	0.51	0.69	0.57
xcon	0.06	-0.01	0.01	0.00	0.01	0.75	0.08	0.86	0.56	-0.30	0.59	0.32	0.23	0.90	1.00	0.85	0.99	0.98	0.05	-0.66	0.67	0.63	0.64	0.68
xprecon	0.03	-0.01	0.00	0.00	0.01	0.72	0.01	0.73	0.76	-0.32	0.49	0.46	0.18	0.93	0.85	1.00	0.85	0.88	0.10	-0.61	0.65	0.44	0.77	0.50
xRM	0.05	-0.01	0.00	-0.01	0.01	0.78	0.10	0.88	0.56	-0.31	0.58	0.31	0.27	0.92	0.99	0.85	1.00	0.98	0.05	-0.63	0.65	0.58	0.62	0.65
xURM	0.06	0.00	0.01	0.01	0.02	0.76	0.08	0.88	0.59	-0.30	0.60	0.34	0.23	0.91	0.98	0.88	0.98	1.00	0.05	-0.65	0.65	0.58	0.66	0.64
xMH	-0.01	-0.09	-0.06	-0.08	-0.10	0.17	0.06	0.05	0.11	-0.12	-0.01	0.07	0.06	0.08	0.05	0.10	0.05	0.05	1.00	-0.28	0.03	-0.05	0.08	-0.04
x%wood	-0.04	-0.01	-0.01	-0.02	-0.02	-0.29	0.17	-0.55	-0.50	0.39	-0.72	-0.49	0.22	-0.64	-0.66	-0.61	-0.63	-0.65	-0.28	1.00	-0.93	-0.87	-0.85	-0.90
x%steel	0.04	0.03	0.03	0.04	0.05	0.32	-0.16	0.54	0.58	-0.38	0.69	0.58	-0.18	0.70	0.67	0.65	0.65	0.65	0.03	-0.93	1.00	0.86	0.88	0.89
x%con	0.05	0.04	0.03	0.04	0.05	0.19	-0.15	0.48	0.31	-0.29	0.67	0.30	-0.24	0.51	0.63	0.44	0.58	0.58	-0.05	-0.87	0.86	1.00	0.64	0.97
x%precon	0.03	0.03	0.03	0.05	0.05	0.39	-0.14	0.58	0.66	-0.40	0.71	0.62	-0.10	0.69	0.64	0.77	0.62	0.66	0.08	-0.85	0.88	0.64	1.00	0.72
x%RM	0.05	0.03	0.03	0.04	0.05	0.25	-0.14	0.56	0.35	-0.33	0.75	0.34	-0.20	0.57	0.68	0.50	0.65	0.64	-0.04	-0.90	0.89	0.97	0.72	1.00
x%URM	0.07	0.07	0.05	0.07	0.08	0.22	-0.14	0.54	0.36	-0.30	0.73	0.35	-0.22	0.54	0.64	0.50	0.60	0.66	-0.05	-0.84	0.83	0.88	0.73	0.89
x%MH	-0.02	-0.09	-0.06	-0.08	-0.09	-0.02	-0.07	-0.04	0.01	-0.09	-0.06	0.02	-0.11	-0.02	-0.05	-0.01	-0.05	-0.05	0.88	-0.26	-0.03	-0.09	0.00	-0.09
xW1	0.11	0.53	0.45	0.48	0.46	0.08	0.25	0.05	0.01	0.21	0.04	-0.01	0.13	0.00	0.02	-0.01	0.02	0.02	-0.09	0.08	-0.05	-0.05	-0.04	-0.04
xC2L	0.10	0.30	0.23	0.27	0.25	0.29	0.09	0.47	0.28	-0.08	0.41	0.22	0.07	0.37	0.45	0.33	0.44	0.44	-0.03	-0.34	0.34	0.34	0.31	0.37
xRM1L	0.11	0.34	0.28	0.31	0.29	0.29	0.12	0.46	0.24	-0.05	0.39	0.19	0.09	0.34	0.41	0.29	0.42	0.41	-0.03	-0.29	0.30	0.29	0.27	0.33
x%W1	0.12	0.59	0.49	0.54	0.50	-0.05	0.10	0.05	0.01	0.20	0.10	0.03	-0.07	0.00	0.01	-0.01	0.01	0.02	-0.10	0.00	0.03	0.04	0.02	0.04
x%C2L	0.12	0.59	0.49	0.54	0.50	-0.05	0.09	0.05	0.01	0.20	0.09	0.03	-0.06	0.00	0.01	-0.01	0.01	0.02	-0.10	-0.01	0.03	0.04	0.02	0.04
x%RM1L	0.12	0.58	0.49	0.53	0.49	-0.04	0.10	0.05	0.01	0.20	0.09	0.03	-0.06	0.00	0.01	-0.01	0.01	0.02	-0.09	0.00	0.02	0.03	0.02	0.04
xyrblt	-0.04	-0.10	-0.06	-0.10	-0.10	0.23	0.05	0.00	0.06	-0.21	-0.09	0.02	0.27	0.06	0.03	0.07	0.04	0.02	0.27	-0.01	-0.04	-0.12	0.00	-0.10
x%pre70	0.03	0.13	0.08	0.14	0.12	-0.24	-0.03	-0.03	-0.06	0.24	0.05	-0.01	-0.26	-0.09	-0.07	-0.09	-0.08	-0.07	-0.26	0.06	0.00	0.04	-0.02	0.03
xOHU	0.01	-0.12	-0.08	-0.12	-0.10	0.41	0.33	0.02	-0.03	-0.18	-0.13	-0.14	0.55	0.04	0.08	0.00	0.09	0.11	0.18	0.09	-0.13	-0.10	-0.14	-0.10
xgas	0.00	-0.11	-0.09	-0.09	-0.10	0.38	0.33	-0.02	-0.04	-0.14	-0.18	-0.14	0.56	0.00	0.02	-0.03	0.04	0.04	0.18	0.16	-0.19	-0.19	-0.17	-0.19
xelec	0.01	-0.08	-0.01	-0.11	-0.05	0.26	0.16	0.10	0.01	-0.17	0.05	-0.06	0.25	0.13	0.21	0.06	0.19	0.23	0.06	-0.12	0.09	0.17	0.01	0.15
x%gas	-0.03	-0.09	-0.06	-0.07	-0.07	0.06	0.13	-0.07	-0.02	0.07	-0.13	-0.06	0.16	-0.06	-0.11	-0.05	-0.08	-0.12	0.02	0.20	-0.19	-0.26	-0.12	-0.22
x%elec	0.01	-0.11	0.01	-0.14	-0.05	0.12	-0.01	0.16	0.04	-0.16	0.17	0.02	0.01	0.15	0.24	0.11	0.21	0.24	0.00	-0.24	0.21	0.30	0.11	0.28
xpop	0.00	-0.03	-0.07	-0.02	-0.04	0.24	0.08	-0.09	-0.05	-0.26	-0.24	-0.11	0.38	-0.02	-0.02	-0.04	-0.01	-0.01	0.15	0.13	-0.15	-0.14	-0.15	-0.16
xdens	0.07	0.12	0.07	0.12	0.14	-0.22	-0.08	-0.06	-0.12	0.15	0.00	-0.11	-0.26	-0.07	0.00	-0.11	-0.04	0.03	-0.18	-0.05	0.07	0.22	-0.08	0.16
xarea	-0.01	-0.06	-0.04	-0.07	-0.08	0.05	0.02	-0.03	-0.02	-0.05	-0.07	-0.02	0.06	-0.02	-0.02	-0.02	-0.02	-0.04	0.26	-0.03	-0.04	-0.04	-0.04	-0.05
xlowres	-0.01	-0.03	-0.03	-0.01	-0.02	0.33	0.06	0.14	0.24	-0.24	0.06	0.18	0.26	0.26	0.18	0.28	0.20	0.18	0.12	-0.10	0.12	0.00	0.19	0.02
xhires	0.01	0.00	-0.06	0.05	-0.02	0.38	0.00	0.32	0.43	-0.29	0.28	0.38	0.15	0.43	0.37	0.48	0.37	0.38	0.13	-0.35	0.36	0.24	0.43	0.26
xCIT	-0.01	-0.08	-0.07	-0.07	-0.09	0.32	-0.01	0.20	0.32	-0.28	0.13	0.26	0.18	0.32	0.25	0.36	0.26	0.25	0.19	-0.24	0.24	0.12	0.30	0.13
x%lowres	0.04	0.16	0.11	0.18	0.19	-0.19	-0.04	-0.01	-0.04	0.18	0.05	-0.02	-0.24	-0.03	-0.02	-0.04	-0.03	0.01	-0.21	0.01	0.04	0.08	0.00	0.07
x%hires	0.05	0.20	0.05	0.24	0.17	-0.11	-0.12	0.15	0.07	0.03	0.27	0.10	-0.28	0.12	0.18	0.10	0.14	0.20	-0.14	-0.29	0.30	0.38	0.22	0.35
x%CIT	0.00	0.12	0.05	0.16	0.13	-0.05	-0.10	0.18	0.19	-0.01	0.29	0.23	-0.23	0.18	0.18	0.19	0.16	0.20	-0.14	-0.28	0.32	0.29	0.31	0.29

* Variables are defined in Table 2-1.

Table B-2. Correlation matrix for Dataset B (2nd half)

	x%URM	*x%MH*	*xW1*	*xC2L*	*xRM1L*	*x%W1*	*x%C2L*	*x%RM1L*	*xyrblt*	*x%pre70*	*xOHU*	*xgas*	*xelec*	*x%gas*	*x%elec*	*xpop*	*xdens*	*xarea*	*xlowres*	*xhires*	*xCIT*	*x%lowres*	*x%hires*	*x%CIT*
y	0.07	-0.02	0.11	0.10	0.11	0.12	0.12	0.12	-0.04	0.03	0.01	0.00	0.01	-0.03	0.01	0.00	0.07	-0.01	-0.01	0.01	-0.01	0.04	0.05	0.00
xpga	0.07	-0.09	0.53	0.30	0.34	0.59	0.59	0.58	-0.10	0.13	-0.12	-0.11	-0.08	-0.09	-0.11	-0.03	0.12	-0.06	-0.03	0.00	-0.08	0.16	0.20	0.12
xpgv	0.05	-0.06	0.45	0.23	0.28	0.49	0.49	0.49	-0.06	0.08	-0.08	-0.09	-0.01	-0.06	0.01	-0.07	0.07	-0.04	-0.03	-0.06	-0.07	0.11	0.05	0.05
xsa	0.07	-0.08	0.48	0.27	0.31	0.54	0.54	0.53	-0.10	0.14	-0.12	-0.09	-0.11	-0.07	-0.14	-0.02	0.12	-0.07	-0.01	0.05	-0.07	0.18	0.24	0.16
xii	0.08	-0.09	0.46	0.25	0.29	0.50	0.50	0.49	-0.10	0.12	-0.10	-0.10	-0.05	-0.07	-0.05	-0.04	0.14	-0.08	-0.02	-0.02	-0.09	0.19	0.17	0.13
tbldg	0.22	-0.02	0.08	0.29	0.29	-0.05	-0.05	-0.04	0.23	-0.24	0.41	0.38	0.26	0.06	0.12	0.24	-0.22	0.05	0.33	0.38	0.32	-0.19	-0.11	-0.05
xrbldg	-0.14	-0.07	0.25	0.09	0.12	0.10	0.09	0.10	0.05	-0.03	0.33	0.33	0.16	0.13	-0.01	0.08	-0.08	0.02	0.06	0.00	-0.01	-0.04	-0.12	-0.10
xcbldg	0.54	-0.04	0.05	0.47	0.46	0.05	0.05	0.05	0.00	-0.03	0.02	-0.02	0.10	-0.07	0.16	-0.09	-0.06	-0.03	0.14	0.32	0.20	-0.01	0.15	0.18
xibldg	0.36	0.01	0.01	0.28	0.24	0.01	0.01	0.01	0.06	-0.06	-0.03	-0.04	0.01	-0.02	0.04	-0.05	-0.12	-0.02	0.24	0.43	0.32	-0.04	0.07	0.19
x%rbldg	-0.30	-0.09	0.21	-0.08	-0.05	0.20	0.20	0.20	-0.21	0.24	-0.18	-0.14	-0.17	0.07	-0.16	-0.26	0.15	-0.05	-0.24	-0.29	-0.28	0.18	0.03	-0.01
x%cbldg	0.73	-0.06	0.04	0.41	0.39	0.10	0.09	0.09	-0.09	0.05	-0.13	-0.18	0.05	-0.13	0.17	-0.24	0.00	-0.07	0.06	0.28	0.13	0.05	0.27	0.29
x%ibldg	0.35	0.02	-0.01	0.22	0.19	0.03	0.03	0.03	0.02	-0.01	-0.14	-0.14	-0.06	-0.06	0.02	-0.11	-0.11	-0.02	0.18	0.38	0.26	-0.02	0.10	0.23
xwood	-0.22	-0.11	0.13	0.07	0.09	-0.07	-0.06	-0.06	0.27	-0.26	0.55	0.56	0.25	0.16	0.01	0.38	-0.26	0.06	0.26	0.15	0.18	-0.24	-0.28	-0.23
xsteel	0.54	-0.02	0.00	0.37	0.34	0.00	0.00	0.00	0.06	-0.09	0.04	0.00	0.13	-0.06	0.15	-0.02	-0.07	-0.02	0.26	0.43	0.32	-0.03	0.12	0.18
xcon	0.64	-0.05	0.02	0.45	0.41	0.01	0.01	0.01	0.03	-0.07	0.08	0.02	0.21	-0.11	0.24	-0.02	0.00	-0.02	0.18	0.37	0.25	-0.02	0.18	0.18
xprecon	0.50	-0.01	-0.01	0.33	0.29	-0.01	-0.01	-0.01	0.07	-0.09	0.00	-0.03	0.06	-0.05	0.11	-0.04	-0.11	-0.02	0.28	0.48	0.36	-0.04	0.10	0.19
xRM	0.60	-0.05	0.02	0.44	0.42	0.01	0.01	0.01	0.04	-0.08	0.09	0.04	0.19	-0.08	0.21	-0.01	-0.04	-0.02	0.20	0.37	0.26	-0.03	0.14	0.16
xURM	0.66	-0.05	0.02	0.44	0.41	0.02	0.02	0.02	0.02	-0.07	0.11	0.04	0.23	-0.12	0.24	-0.01	0.03	-0.04	0.18	0.38	0.25	0.01	0.20	0.20
xMH	-0.05	0.88	-0.09	-0.03	-0.03	-0.10	-0.10	-0.09	0.27	-0.26	0.18	0.18	0.06	0.02	0.00	0.15	-0.18	0.26	0.12	0.13	0.19	-0.21	-0.14	-0.14
x%wood	-0.84	-0.26	0.08	-0.34	-0.29	0.00	-0.01	0.00	-0.01	0.06	0.09	0.16	-0.12	0.20	-0.24	0.13	-0.05	-0.03	-0.10	-0.35	-0.24	0.01	-0.29	-0.28
x%steel	0.83	-0.03	-0.05	0.34	0.30	0.03	0.03	0.02	-0.04	0.00	-0.13	-0.19	0.09	-0.19	0.21	-0.15	0.07	-0.04	0.12	0.36	0.24	0.04	0.30	0.32
x%con	0.88	-0.09	-0.05	0.34	0.29	0.04	0.04	0.03	-0.12	0.04	-0.10	-0.19	0.17	-0.26	0.30	-0.14	0.22	-0.04	0.00	0.24	0.12	0.08	0.38	0.29
x%precon	0.73	0.00	-0.04	0.31	0.27	0.02	0.02	0.02	0.00	-0.02	-0.14	-0.17	0.01	-0.12	0.11	-0.15	-0.08	-0.04	0.19	0.43	0.30	0.00	0.22	0.31
x%RM	0.89	-0.09	-0.04	0.37	0.33	0.04	0.04	0.04	-0.10	0.03	-0.10	-0.19	0.15	-0.22	0.28	-0.16	0.16	-0.05	0.02	0.26	0.13	0.07	0.35	0.29
x%URM	1.00	-0.10	-0.02	0.36	0.31	0.07	0.07	0.06	-0.12	0.04	-0.05	-0.15	0.25	-0.30	0.33	-0.12	0.33	-0.09	-0.01	0.25	0.08	0.16	0.48	0.36
x%MH	-0.10	1.00	-0.10	-0.06	-0.07	-0.10	-0.09	-0.09	0.23	-0.22	0.09	0.09	0.01	0.02	0.00	0.07	-0.16	0.24	0.04	0.05	0.13	-0.20	-0.13	-0.14
xW1	-0.02	-0.10	1.00	0.50	0.60	0.91	0.91	0.91	-0.04	0.08	0.03	0.04	0.01	0.03	-0.04	-0.03	0.01	-0.06	-0.01	-0.03	-0.08	0.10	0.05	0.04
xC2L	0.36	-0.06	0.50	1.00	0.98	0.54	0.54	0.54	-0.03	0.03	0.02	-0.01	0.11	-0.09	0.09	-0.04	0.04	-0.04	0.05	0.17	0.06	0.07	0.19	0.17
xRM1L	0.31	-0.07	0.60	0.98	1.00	0.62	0.62	0.62	-0.03	0.04	0.03	0.00	0.10	-0.06	0.07	-0.05	0.01	-0.04	0.05	0.14	0.04	0.07	0.16	0.15
x%W1	0.07	-0.10	0.91	0.54	0.62	1.00	1.00	0.99	-0.08	0.12	-0.10	-0.10	-0.05	-0.06	-0.06	-0.09	0.09	-0.07	-0.05	-0.03	-0.10	0.16	0.17	0.11
x%C2L	0.07	-0.09	0.91	0.54	0.62	1.00	1.00	1.00	-0.08	0.11	-0.10	-0.09	-0.05	-0.06	-0.06	-0.09	0.09	-0.07	-0.05	-0.03	-0.09	0.16	0.16	0.11
x%RM1L	0.06	-0.09	0.91	0.54	0.62	0.99	1.00	1.00	-0.07	0.11	-0.10	-0.09	-0.04	-0.05	-0.05	-0.09	0.08	-0.07	-0.05	-0.04	-0.09	0.15	0.15	0.11
xyrblt	-0.12	0.23	-0.04	-0.03	-0.03	-0.08	-0.08	-0.07	1.00	-0.89	0.22	0.16	0.25	-0.11	0.24	0.29	-0.35	0.10	0.16	0.17	0.23	-0.45	-0.22	-0.18
x%pre70	0.04	-0.22	0.08	0.03	0.04	0.12	0.11	0.11	-0.89	1.00	-0.23	-0.16	-0.29	0.16	-0.29	-0.28	0.26	-0.10	-0.10	-0.14	-0.21	0.46	0.21	0.20
xOHU	-0.05	0.09	0.03	0.02	0.03	-0.10	-0.10	-0.10	0.22	-0.23	1.00	0.95	0.64	0.32	0.25	0.63	-0.03	0.00	0.32	0.17	0.17	-0.10	-0.14	-0.15
xgas	-0.15	0.09	0.04	-0.01	0.00	-0.10	-0.09	-0.09	0.16	-0.16	0.95	1.00	0.36	0.46	-0.01	0.64	-0.08	-0.03	0.35	0.19	0.18	-0.07	-0.16	-0.15
xelec	0.25	0.01	0.01	0.11	0.10	-0.05	-0.05	-0.04	0.25	-0.29	0.64	0.36	1.00	-0.18	0.76	0.31	0.11	0.00	0.09	0.06	0.05	-0.08	-0.02	-0.05
x%gas	-0.30	0.02	0.03	-0.09	-0.06	-0.06	-0.06	-0.05	-0.11	0.16	0.32	0.46	-0.18	1.00	-0.24	-0.19	-0.23	-0.06	0.03	-0.11	-0.04	0.03	-0.24	-0.09
x%elec	0.33	0.00	-0.04	0.09	0.07	-0.06	-0.06	-0.05	0.24	-0.29	0.25	-0.01	0.76	-0.24	1.00	-0.08	0.06	0.03	-0.10	-0.08	-0.02	-0.11	-0.04	-0.02
xpop	-0.12	0.07	-0.03	-0.04	-0.05	-0.09	-0.09	-0.09	0.29	-0.28	0.63	0.64	0.31	-0.19	-0.08	1.00	0.08	0.01	0.45	0.32	0.25	-0.08	-0.01	-0.07
xdens	0.33	-0.16	0.01	0.04	0.01	0.09	0.09	0.08	-0.35	0.26	-0.03	-0.08	0.11	-0.23	0.06	0.08	1.00	-0.13	-0.26	-0.16	-0.29	0.40	0.61	0.22
xarea	-0.09	0.24	-0.06	-0.04	-0.04	-0.07	-0.07	-0.07	0.10	-0.10	0.00	-0.03	0.00	-0.06	0.03	0.01	-0.13	1.00	-0.02	0.04	0.24	-0.18	-0.13	-0.18
xlowres	-0.01	0.04	-0.01	0.05	0.05	-0.05	-0.05	-0.05	0.16	-0.10	0.32	0.35	0.09	0.03	-0.10	0.45	-0.26	-0.02	1.00	0.68	0.57	0.18	-0.10	0.06
xhires	0.25	0.05	-0.03	0.17	0.14	-0.03	-0.03	-0.04	0.17	-0.14	0.17	0.19	0.06	-0.11	-0.08	0.32	-0.16	0.04	0.68	1.00	0.78	-0.08	0.24	0.31
xCIT	0.08	0.13	-0.08	0.06	0.04	-0.10	-0.09	-0.09	0.23	-0.21	0.17	0.18	0.05	-0.04	-0.02	0.25	-0.29	0.24	0.57	0.78	1.00	-0.27	-0.11	0.14
x%lowres	0.16	-0.20	0.10	0.07	0.07	0.16	0.16	0.15	-0.45	0.46	-0.10	-0.07	-0.08	0.03	-0.11	-0.08	0.40	-0.18	0.18	-0.08	-0.27	1.00	0.32	0.22
x%hires	0.48	-0.13	0.05	0.19	0.16	0.17	0.16	0.15	-0.22	0.21	-0.14	-0.16	-0.02	-0.24	-0.04	-0.01	0.61	-0.13	-0.10	0.24	-0.11	0.32	1.00	0.50
x%CIT	0.36	-0.14	0.04	0.17	0.15	0.11	0.11	0.11	-0.18	0.20	-0.15	-0.15	-0.05	-0.09	-0.02	-0.07	0.22	-0.18	0.06	0.31	0.14	0.22	0.50	1.00

* Variables are defined in Table 2-1.

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