An Analysis of the Determinants of Industrial Property Valuation

*Frank A. Fehribach**
*Ronald C. Rutherford***
*Mark E. Eakin****

Abstract. **Recent research investigated the relationship between physical factors and the asking price of industrial buildings. We extend prior research by including physical, locational, financial and economic variables to determine the factors that influence the sales price. This research provides an initial valuation framework for appraisers and is a first step toward the development of an industrial property index. Eleven variables—building size, office space, dock doors, ceiling height, age, distance to the Dallas/Fort Worth Airport, county of sale, industrial cap rate, prime rate, tenant type, and date of sale—are found to explain the sales price of industrial property.**

Introduction

The value of a real estate property depends upon a number of factors. These factors may include the property's physical characteristics, location attributes, financial traits and market economic conditions. It is these factors that appraisers use in calculating the value of real property.

By identifying the factors that explain industrial sale prices, this research provides an initial framework for appraisers and is a first step in creating an industrial property index. Identification of variables that explain the price of industrial property at a given point in time is a necessary but not sufficient condition for creating an index. If the variables are available in the market, then the expected price of industrial properties can be calculated based on these variables even when a current sales price is not available. Thus, a sales price index based on actual sales when available and on expected sale prices when sales are not available would provide the most representative index.

This paper focuses on estimating a pricing model, using Ordinary Least Squares (OLS) and Weighted Least Squares (WLS), to explain the sales price of industrial properties in Dallas/Fort Worth. The model measures the extent each variable affects the sales price through its parameter coefficient, and builds on the limited research in the area of industrial property valuation.

In the next section we review the literature and discuss prior research in the areas of residential property valuation, hedonic pricing models, and valuation of industrial property. In section three, we discuss the data and methodology included in our analysis. In the fourth section, we report the results of our research and analysis. And, in section five, we state our conclusions.

*Arthur Anderson & Co., Valuation Services, Dallas, Texas 75202.
**Department of Finance & Real Estate, University of Texas at Arlington, Arlington, Texas 76019-0449.
***Department of Information Systems and Management Sciences, University of Texas at Arlington, Arlington, Texas 76019-0449.
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Literature Review

Numerous articles have been written concerning the use of multiple regression analysis to value residential housing and land. The first application of multiple regression to value property was by G. C. Haas in 1922.[1] Robert A. Blettner (1969), Billie Ann Brotman (1990), Frank C. Emerson (1972), Jonathon Mark and Michael Goldberg (1988), and Ravindra Kamath and Kenneth R. Yantek (1979) all produced research papers on valuing single-family homes with multiple regression analysis. Additionally, William Shenkel (1975), and Kang and Reichert (1988) used multiple regression analysis on multitenant residential buildings.

Henry C. Entreken Jr. (1984), Roland E. Nelson and Jay L. Messer (1990) and Donald H. Treadwell (1988) produced nonstatistical articles on industrial properties. Entreken's article dealt with problems in appraising industrial properties. In his article, Entreken indicated that the location of an industrial building may have more effect on value than other physical factors.[2] This differed from other articles on real property value that emphasized the physical factors of a property. Nelson and Messer's, and Treadwell's articles also dealt with the problems of valuing industrial properties. Nelson and Messer focused their attention toward older industrial buildings that suffer from functional obsolescence. Treadwell's article discussed the use of the Cost Approach in valuing industrial properties. Since industrial properties are many times considered by appraisers as special use properties, the use of the Cost Approach takes on more significance.

James W. Hoag (1980) published an article on the subject of valuing industrial property through regression analysis. In his article, "Toward Indices of Real Estate Value and Return," Hoag proposes the need for an index of value and return for industrial properties. Hoag's proposed model attempts to mimic an appraiser by basing the industrial property's value on microeconomic and macroeconomic factors, and not just physical factors.[3] That is, Hoag's model attempts to include the income, sales comparison and cost approaches to value.

Brent W. Ambrose (1990) used multiple regression analysis, both Ordinary Least Squares and Weighted Least Squares, to explain variations in the asking price and quoted rents of light industrial buildings. In this paper Ambrose used industrial asking prices and asking rents. In his opinion, both were close to the eventual sales price and executed lease rate. This differed from the previous analysis of James W. Hoag who had used actual sale prices. Additionally, Ambrose focused his model on the physical attributes of a property, neglecting locational, financial and economic variables related to the industrial property. He supported the limiting of the valuation model to property characteristic variables based on the previous work W. M. Shenkel had done on multifamily properties. This study extends research by Hoag and Ambrose to further refine a hedonic pricing model for industrial sales.

Data Selection and Methodology

Thirteen independent variables are included in the analysis. This data is a combination of primary source data that is specific for each industrial property sale, and secondary source data, which is published in a variety of reference sources. These

variables represented physical, locational, economic and financial characteristics of industrial property. Ambrose focused his research on property characteristics and did not include location, economic and financial variables. Hoag indicates the importance of including these other variables, but the interpretation of individual coefficients in his model is impossible due to the multicollinearity of the independent variables. Thus, while Hoag suggests the valuation model should include all three appraisal approaches (cost, income and sales comparison), it is up to other researchers to determine the variables.

Primary Data

Primary data was gathered, where possible, from the sales of 228 industrial buildings. Two appraisal firms, one in Dallas County and the other in Tarrant County, as well as a financial institution's appraisal department, were consulted for the sales. These three sources provided data sheets on each property. Since the data sheets are not standardized some of them did not contain all of the primary data variables. This fact reduced the number of observations of some variables. However, the data sheets provided by these sources contributed most of the physical characteristics of any given property sale, as well as the sales price. Some of the variables used that relate to Ambrose's research are building size, office size, ceiling height, rail siding, dock doors and age of the building.

For locational factors, this report used the variables: county, a dummy variable where Dallas County = 1 and Tarrant County = 0, and distance relative to the Dallas/Fort Worth Airport. To obtain the distance from the airport, a measurement was taken from the property's location on the map to a point in the center of the Dallas/Fort Worth Airport that was selected for consistent measurement. The measurement of the variable was calculated by the most direct route, and rounded to the nearest quarter mile.

Secondary Data

Secondary source data was provided by both government agencies and private companies. The Federal Reserve Bank of Dallas provided information on the Texas Industrial Production Index. Nongovernmental secondary sources included the Appraisal Institute's Research Department, which through its publications in *The Appraiser*, provided the Industrial Conventional Loan Rate. Standard and Poor's Statistical Service publication listed the Prime Rate for major banks. Data Resources, Inc., provided the *Dallas Morning News Index*. National and local capitalization rates were obtained from the National Real Estate Index's publication, *The Market Monitor*. Finally, the Real Estate Research Corporation contributed its national Industrial Capitalization Rate survey for this paper.

Physical Variables

We include independent variables that Ambrose included in his research if they are available. This includes *Building Size, Office Size, Dock Doors*, and *Rail Siding*. Additionally, the variables *Ceiling Height* and *Age*, which Ambrose found as not significant or did not use, respectively, are included in the regression model. All of

these independent variables represent physical characteristics of an industrial building, and are described in detail below.

Building Size is based on the net rentable area of the industrial building in square feet. Some people consider building size in cubic feet. However, the inclusion of ceiling height should act as a proxy for this. It is expected that the increase in size of a building will increase its sales price or that the relationship will be positive.

Office Space is based on the number of square feet in the industrial building that is finished-out for office use. Once again, we expect a positive relationship since from a cost approach basis of appraising, the office space is more valuable. Thus, an increase in office space should show an increase in sales prices.

Dock Doors is based on the number of dock-high dock doors in an industrial building. There should be a positive relationship between the number of dock doors and the value of an industrial building. However, dock doors may also act as a proxy for size. That is, as the number of dock doors increases so does the size of an industrial building.

Rail Siding is a dummy variable based on whether an industrial building has rail siding or not. In our analysis, a building with rail siding is treated as a dummy variable with a one assigned to properties with rail siding and a zero for properties with no rail siding. Therefore, a positive relationship is expected between rail siding and value.

Ceiling Height is based on the clear ceiling height of the building. It is expected that a positive relationship exists between a building's ceiling height and its sales price. That is, as the ceiling height goes up, producing more cubic feet of building space, so does the price.

Age is based on the year the building was built. Age should have a negative relationship with the value of a building.

Financial Variables

In appraising income-producing industrial buildings (i.e., industrial buildings that are not owner occupied), the income approach is highly regarded. In fact, using the variable NOI, which is the net operating income calculated from the rent rates, percentage leased, and expenses of the industrial buildings, provided a high R^2. That is, this variable explained an industrial building's value better than any other single variable. However, in most cases this variable is not available, and from a practical perspective observable variables are needed. Thus, this variable is excluded from the model.[4]

Industrial Capitalization Rate is based on the surveyed information of the Real Estate Research Corporation. Capitalization rates are used by appraisers, bankers, and financial analysts to convert income streams into value. This survey is published by the Appraisal Institute for use by commercial appraisers. It is anticipated that a higher capitalization should indicate a lower sales price. Thus, a negative relationship between capitalization rate and value is expected.

Prime Rate is the rate charged by banks to their most creditworthy corporate customers. This rate is very important in real estate finance, because many construction loans are based on it (i.e., most construction loans are financed at a certain

number of basis points above the prime rate), and it provides an indication of the interest rate that an investor can obtain to finance the purchase of an industrial building. Since most real estate purchases are financed, the prime rate is an indication of the cost an investor experiences through his acquisition. Therefore, we expect a negative relationship between the prime rate and the value of an industrial property.

Location Variables

Two location variables were collected. **County** represents ether Dallas or Tarrant Counties. The variable county is included to determine if the location of an industrial building in Dallas or Tarrant County has an effect on the sales price of the building. A dummy variable is used with one representing Dallas County and zero depicting Tarrant County. Because Dallas is larger, and has larger manufacturing and distribution industries, it is anticipated the relationship will be positive.

Distance from the Dallas/Fort Worth Airport is directly measured from the industrial building address to the center of the Dallas/Fort Worth Airport. As air transportation of industrial products and components becomes a primary consideration for locating manufacturing and distribution facilities, especially amongst the high tech showroom industrial buildings, the distance from Dallas/Fort Worth International Airport becomes a factor to explore. Support for this contention is provided by M/PF Research, Inc. in its *Industrial Market Report* for Dallas/Fort Worth. Its research shows that the area around the airport in Tarrant County attracted the most demand for warehouse space of any submarket over the last eighteen months. Additionally, the area around Dallas/Fort Worth International Airport to the east was in the top eight submarkets in warehouse space demand during the last eighteen months.[5] It is expected that the relationship between the distance from the Dallas/Fort Worth Airport and the sales price of an industrial building will be negative. That is, as the distance from the airport increases, the sales price of the building decreases.

Economic Variables

To study the effect of economic activity on the value of industrial property, several indices were examined. Local indicators of economic activity were considered including indices on employment, consumer price, and industrial production. The **Dallas Morning News Index** variable was chosen because of the thoroughness of the index as an economic indicator for the Dallas/Fort Worth area. The *Dallas Morning News Index* is produced by Data Resources, Inc. The index is a three-month moving average composite of national and local indicators. Included in the index is labor market tightness, average weekly work hours in manufacturing, consumer installment credit, Dallas MSA housing permits, Standard & Poor's Stock Price Index, national inventory and orders, vendor performance, Spot Market Price Index for raw industrial commodities, and money supply based on the M2 category in 1982 dollars. The scope of this index overlaps many of the other economic independent variables considered in this report. Therefore, the other economic variables are excluded to avoid the multicollinearity that occurred.[6] It is expected that a positive relationship

exists between the *Dallas Morning News Index* and the sales price of an industrial building. One would expect a willingness of an investor to pay more during good times than in bad times.

Date of Sale is the year and month of sale. The first observation occurs in January 1987 and the last observation occurs in May of 1991.

Hybrid Variable

The final variable included in our model is a hybrid between physical characteristics (building design) and financial characteristics (income-producing property).

Type of Tenant is a dummy variable between multitenant and single-tenant buildings. In our analysis, multitenant buildings are given a zero and single-tenant buildings are given a one. Many single-tenant industrial buildings are owner occupied. Consequently, the reasons surrounding their purchase differ from a multitenant building, which is almost always an income-producing building. The importance of this variable is to determine if the design and use of an industrial building (i.e., multitenant or single-tenant) effects the value of the building. A positive relationship should exist between this variable and the sales price of an industrial building. It is commonly perceived in the appraisal field that an owner-occupied grantor is more likely to pay a higher price because of his motivations. Therefore, a positive correlation should exist. Exhibit 1 displays the independent variables used in the hedonic pricing model, the expected sign and a brief description.

The number of observations, mean, standard deviation, and standard error of mean for the dependent and independent variables are displayed in Exhibit 2. Five additional variables are listed that relate to Notes 4 and 6.

Exhibit 1
Independent Variables

Independent Variable	Expected Sign	Description
Building Size (BLD)	+	Net Rentable Sq. Ft. of Building
Office Space (OFF)	+	Total Office Sq. Ft. of Building
Dock Doors (DD)	+	Number of Dock-High Dock Doors
Rail Siding (RS)	+	0 or 1 indicating Railroad Siding
Ceiling Height (CH)	+	Clear Ceiling Height of Building
Age (AGE)	−	Age of Building
Ind. Cap. Rate (ICR)	−	Industrial Cap. Rate
Prime Rate (PR)	−	Prime Rate on Date of Sale
County (CO)	+	Dallas Co. = 1, Tarrant Co. = 0
Distance from DFW Airport (LAP)	−	Distance from Building to DFW Airport
Dallas Morning News Index (DMNI)	+	Economic Activity Index for DFW
Type of Tenant (TT)	+	Single-Tenant = 1, Multitenant = 0
Date of Sale (DATE)	±	Year and Month of Sale

Exhibit 2
Summary

Variable	*N*	Mean	Standard Deviation	Standard Error of Mean
Sales Price	170	1094413.00	1400415.00	107407.00
Building Size	170	46807.00	58607.00	4495.00
Office Space	170	7966.00	13989.00	1073.00
Dock Doors	170	5.22	7.16	.55
Rail Siding	170	.39	.49	.04
Ceiling Height	170	17.88	3.85	.30
AGE	170	13.84	8.62	.66
Ind. Cap Rate	170	8.54	.47	.04
Prime Rate	170	9.84	.96	.07
County	170	.61	.49	.04
Distance-Airport	170	12.08	5.50	.42
Dallas News Index	170	111.08	1.14	.09
Type of Tenant	170	.71	.45	.04
Date of Sale	170	89.03	1.07	.08
Local CPI	154	120.65	4.48	.36
Local Unemployment	154	5.53	.55	.04
Texas Ind. Prod.	154	106.35	1.86	.15
Ind. Building ($)	108	10468648	13343505	1283979
Exp. Gross Inc.	99	155755	192874	19385
NOI	77	150617	182976	20852

Model Selection

In the selection of the thirteen independent variables, it is assumed that a linear relationship exists between these variables and the industrial building's sale prices. Thus, a linear regression model can be fitted using ordinary least squares (OLS). Therefore, we can specify our linear equation as:

Sales Price (SP) = f (Building Size (BLD), Office Space (OFF), Dock Doors (DD), Rail Siding (RS), Ceiling Height (CH), (AGE), Industrial Cap Rate (ICR), Prime Rate (PR), County (CO), Distance from D/FW Airport (LAP), Dallas Morning News Index (DMNI), Type of Tenant (TT), Date of Sale (DATE)).

From this our model can be specified as:

$$SP = \beta_1 + \beta_2\, BLD + \beta_3\, OFF + \beta_4\, DD + \beta_5\, RS + \beta_6 CH + \beta_7\, AGE + \beta_8\, ICR + \beta_9\, PR + \beta_{10}\, CO + \beta_{11}\, LAP + \beta_{12}\, DMNI + \beta_{13}\, TT + \beta_{13}\, DATE + \varepsilon.$$

Multicollinearity

The variance inflation factor (VIF) is calculated for each independent variable to determine if the variables display collinearity amongst themselves. Exhibit 3 presents the VIF of each variable.

Neter, Wasserman and Kutner's[7] rule of thumb associated with the variance

Exhibit 3
Multicollinearity Determination

Variable	Variance Inflation Factor
Building Size	2.72795129
Office Space	1.44278396
Dock Doors	2.68358264
Rail Siding	1.13661132
Ceiling Height	1.51730556
AGE	1.27627634
Ind. Cap Rate	1.40440650
Prime Rate	1.72363421
County	1.09340505
Distance to Airport	1.08662966
Dallas Morn. News	1.45575264
Type of Tenant	1.34563107
Date of Sale	1.73935551
Total	21.82677874
Average	1.81889823

inflation factor is that an independent variable with a variance inflation factor above 10 or the mean of all of the independent variables significantly above 1 would indicate a severe effect on the regression model. None of the variables chosen for this model indicated a variance inflation factor above 10, and the mean was below 2. Consequently, multicollinearity does not appear to be a major concern, and no remedial methods, such as ridge regression, need to be performed. Additionally, Ambrose did not experience any difficulties with multicollinearity in his study. Ambrose did experience a problem with heteroscedasticity, and we found that our data is not homoscedastic; we corrected for heteroscedasticity by running a weighted least squares (WLS) regression.[8]

Results

OLS Regression Results

As shown in Exhibit 4, the thirteen independent variables explain 96.82% of the variation in the sale price of the industrial building. Because of missing variables, there are only 170 total observations. However, according to the *F*-test, the equation is significant at less than the 1% level with a high *F*-value of 365.471. Therefore, there is sufficient evidence to reject the null hypothesis. Consequently, the model appears to fulfil the Goodness of Fit requirement of a good model, and produces a high R^2 and *F*-value.

The individual parameter estimates calculated for each independent variable by this model are also in Exhibit 4. A *T*-Test is calculated for each variable to test the hypothesis that the coefficient derived from the OLS regression is significant in explaining the sales price of industrial buildings.

Exhibit 4
Analysis of Variance

Source	Degrees of Freedom	*F*-value	Prob > *F*	R^2	R^2_a
Model	13	365.471	.0001	96.82%	96.56%
Error	156				
Total	169				

Regression Parameter Estimates

Variable	Degrees of Freedom	Parameter Estimate	*T* for H_o Parameter = 0	Prob > | *T*|
Intercept	1	3812181	.988	.3245
Building Size	1	14.94	26.513	.0001**
Office Space	1	39.64	23.091	.0001**
Dock Doors	1	19448.33	4.253	.0001**
Rail Siding	1	8058.37	.185	.8532
Ceiling Height	1	15428.96	2.412	.0170**
AGE	1	−5144.48	−1.963	.0514*
Ind. Cap Rate	1	−74472.60	−1.471	.1434
Prime Rate	1	−53745.49	−1.966	.0511*
County	1	98478.11	2.303	.0226**
Distance to Airport	1	−7583.27	−2.000	.0472**
Dallas Morn. News	1	145.19	.007	.9946
Type of Tenant	1	151083.61	2.960	.0036**
Date of Sale	1	−33354.40	−1.349	.1793

**significant at the 5% level
*significant at 10% level
two-tailed tests

From our OLS analysis, at a 5% level there is sufficient evidence available to say that seven variables, *Building Size, Office Space, Dock Doors, Ceiling Height, County, Distance from the Dallas/Fort Worth Airport*, and *Type of Tenant* are significant in explaining the sales price of industrial buildings. Additionally, *Age* and *Prime Rate* are significant at the 10% level. Comparing the actual signs of the coefficients with our expected signs we find each of the variables to be consistent with our expectations. Our results differ from Ambrose's findings in that *Ceiling Height* has the correct sign and is significant and that *Rail Siding* has the expected sign but is insignificant.

Weighted Least Squares Regression

The weighted least squares regression (WLS) provides a slightly better explanation of the sales price of industrial buildings with an adjusted R^2 of 98.01%. That is, 98.01% of the variation in sales price of industrial buildings is explained by the model. Testing the null hypothesis that the model does not explain the sales price of the industrial

Exhibit 5
Weighted Least Squares
Parameter Estimates

Source	Degrees of Freedom	*F*-value	Prob > *F*	R^2	R^2_a
Model	13	642.664	.0001	98.17%	98.01%
Error	156				
Total	169				

Weighted Least Squares
Parameter Estimates

Variable	Degrees of Freedom	Parameter Estimate	*T* for H_o Parameter = 0	Prob > | *T*|
Intercept	1	4942858.00	1.198	.2329
Building Size	1	14.73	33.818	.0001**
Office Space	1	40.54	29.489	.0001**
Dock Doors	1	19587.10	4.994	.0001**
Rail Siding	1	32737.42	.691	.4906
Ceiling Height	1	20594.26	2.982	.0033**
AGE	1	−7065.01	−2.258	.0253**
Ind. Cap Rate	1	−107675.00	−2.005	.0466**
Prime Rate	1	−62197.60	−2.148	.0333**
County	1	98786.33	2.175	.0312**
Distance to Airport	1	−8749.94	−2.066	.0404**
Dallas Morn. News	1	3298.27	.137	.8914
Type of Tenant	1	181357.60	3.252	.0014**
Date of Sale	1	−46904.20	−1.704	.0903*

**significant at a 5% level
*significant at 10% level
two-tailed tests

buildings, the *F*-test produces an *F*-value of 642.664, which is significant at less than 1%. Therefore, we can conclude that the model does explain the sales price of industrial buildings. The number of significant variables at 5% was increased to eleven by weighting the data. The variables *Age, Industrial Cap Rate* and *Prime Rate* are now significant at 5% and the variable *Date of Sale* is now significant at the 10% level. All of the coefficient signs remain the same and the magnitude of the coefficients change only slightly. Exhibit 5 displays the new results from weighting the data.

Conclusions

From the analysis performed in this paper, we find that our model provides a significant degree of explanation of the industrial building sales price variation between January 1987 and May 1991. Thus, this paper accomplishes its goal to extend

the previous research performed by Ambrose to include location, financial and economic factors, and produce a hedonic pricing model for industrial buildings in the Dallas/Fort Worth market.

The model, which included thirteen variables, initially indicated that *Building Size, Office Space*, number of *Dock High Doors, Ceiling Height, Age, Prime Rate, County, Distance to D/FW Airport*, and *Type of Tenant*, are significant variables in the explanation of the sample's sales prices. After weighting the data to correct for heteroscedasticity, the significant variables include all nine listed above plus the *Industrial Cap Rate* and the *Date of Sale*.

We find that *Building Size, Age, Office Space, Ceiling Height* and number of *Dock High Doors* are four physical factors that affect an industrial building's value. An industrial building's distance to the Dallas/Fort Worth Airport and whether it is located in Dallas or Tarrant Counties are two location factors that affect its value. Market conditions that impact the value of industrial property are captured by the *Industrial Cap Rate* and the *Prime Rate* while the *Dallas Morning News Index*, a measure of local conditions, had no relationship. Additionally, the *Type of Tenant* and the *Date of Sale* influenced the sales price of industrial properties in the Dallas/Fort Worth market during the period of study.

In conclusion, the model presented in this paper provides an explanatory model for industrial sales during the period January 1987 to May 1991 in Dallas and Tarrant Counties. Further research must be done to have confidence in a model's predictive abilities. However, this paper does fill a void since the publication of James W. Hoag's paper (1980), and along with Ambrose's (1990) research is one step toward the production of an industrial property value index.

Notes

[1]See p. 502 in Lessinger (1969).

[2]See p. 44 in Entreken (1984).

[3]See p. 569 in Hoag (1980).

[4]With NOI as the only independent variable, the sample is reduced from 170 observations to 77 and the R^2 is 95.71%. The coefficient for NOI is 9.6323 with a t-test of 41.184 that is significant at 1%. When NOI is included along with the thirteen other variables in the paper, the R^2 is 98.40. But the sample is reduced to 77 from 170 observations and NOI exhibits serious collinearity, it has a variance inflation factor (VIF) of 21.12 and BLD has a VIF of 10.46. Given the multicollinearity caused by including NOI and the decrease in sample size, NOI was excluded from the independent variables. The same problems resulted from including expected Gross Income.

[5]See p. 37 in M/PF Research Inc., *Industrial Market Report* (1991).

[6]A model that included *Local Unemployment Rate (LUER), Local Consumer Price Index (LCPI), Texas Industrial Production Index (TIPI)* and *Dallas/Fort Worth Industrial Building Permits (IBP)*, while excluding the *Dallas Morning News Index (DMNI)* was calculated and the results indicated that none of the economic variables are significant in explaining the sales price of industrial properties. All variables were insignificant at the 10% level. This finding is consistent with the insignificant coefficient for the *DMNI*. See Exhibit 2 for summary statistics for these variables. We also regressed *DMNI* against these variables and found an adjusted R^2 of 75% with all four variables significant; thus for the sake of parsimony we used the *DMNI* variable in the paper instead of the economic variables listed above.

[7]See p. 423 in Neter, Wasserman and Kutner (1990).

[8]The White test was employed to test for heteroscedasticity. We rejected the null hypothesis of homoscedasticity and weighted the data using the inverse of the square root of the building size. This is consistent with Ambrose (1990).

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