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Industrial Warehouse Rent Determinants in the Dallas/Fort Worth Area

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***Abstract*. This paper presents the first empirical analysis of the determinants of pooled variation in industrial warehouse rents. It examines industrial warehouse rents using data for seventeen quarterly periods in the Dallas/Fort Worth metroplex. M/PF Research Inc. provided the data. A random effects model is used to estimate the relationship between market rents for industrial properties and various independent variables. Rent per square foot is positively related to the number of grade high doors, and the annual change in net employment. Rent per square foot is negatively effected by ceiling height, percentage of office space, building age, and the presence of a sprinkler system. The results indicate that rents are significantly impacted by physical characteristics, location and general market conditions. Additionally, there is evidence to suggest that the relationship between physical characteristics and rents is nonlinear.**

This paper examines the determinants of industrial warehouse rents in the Dallas/Fort Worth metroplex. It incorporates time-varying market conditions, locational and physical characteristics of the property. These conditions are included by analyzing a panel data set of the Dallas/Fort Worth industrial warehouse market with a random effects model. The data in this sample represent approximately 60% of the entire industrial warehouse market in the D/FW area over a four-year period.

Previous rent determinant studies focused primarily on office and apartment rents, with limited research on retail and industrial rents. Sirmans and Benjamin (1991) review the existing apartment rent literature and conclude that property-specific variables, market incentives and vacancy rates largely determine multifamily rents. Clapp (1993) and Mills (1992) examine office rents and find that property-specific variables, market incentives and vacancy rates determine office rents.

Research on industrial properties is limited. Previous research focused primarily on property value determinants rather than rent determinants. Hoag (1980) developed an industrial property valuation model and estimated an index of property values and returns. Hoag's model attempted to mimic appraisal practice by valuing the property using micro factors, macroeconomic factors and physical factors.

Ambrose (1990) posited a relationship between physical characteristics and industrial property value. Feribach and Rutherford (1993) extended his analysis to include location, financial, economic, and physical components of value.

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Particularly relevant is Ambrose's (1990) analysis of industrial rent determinants. Ambrose modeled variations in quoted rents for light industrial buildings based on the property's physical characteristics. His data set consisted of 388 observations of quoted rents and property characteristics from the Atlanta area in 1986 and 1987. The model estimated by Ambrose explained approximately 23% of the variation in asking rents as a function of the physical characteristics of the property.

Data scarcity accounts for the lack of research into industrial rents. This paper provides empirical evidence about the relationship between industrial warehouse rents, property-specific characteristics, location, and industrial market vacancy using a large panel data set over seventeen quarters.

The paper is organized as follows. The next section examines the model and hypotheses. Later sections discuss data, present empirical results and conclusions.

The Model

Previous research by Ambrose (1990), indicates that industrial rents can be partially explained by the physical characteristics of the property, and local and regional market conditions. His research indicates that industrial rents are a function both of time-invariant characteristics, i.e., physical characteristics, and time-varying characteristics, such as market vacancy rates. The study presented here uses a statistical model and estimation technique that is able to capture both the time-varying and time-invariant properties of rents. A general form for this relationship is:

$$RENT_{jt} = f(PHYCHAR_j, LOC_j, MKT_t)\ . \tag{1}$$

In this study $RENT_{jt}$ is the real rent per square foot for the j^{th} building in the t^{th} quarter; LOC_j is represented as dummy variables for the submarket area of the building; $PHYCHAR_j$ represents the physical characteristics associated with building j; MKT_t reflects market characteristics in the submarket where the property is located (submarket occupancy) and market conditions (net employment) in the Dallas/Fort Worth area at time (t).

The most common approach to estimating rent or value determinants has been to examine a cross-section of rents at a particular point in time (Ambrose, 1990; Sirmans and Benjamin, 1991; Feribach and Rutherford, 1993). Intuitively, a cross-sectional model appears to capture the effects that physical characteristics have on rents, although by its nature it does not capture time-varying effects, such as general economic conditions or changes in vacancy rates. A second possible model is to examine rents or changes in rents over time. Clearly this type of model could capture the time-varying effects, but would not be appropriate for examining time-invariant effects such as physical characteristics in a pooled sample. Neither pure cross-sectional nor pure time-series models are able to completely model the relationship expressed in equation (1).

As shown by Balestra and Nerlove (1966) and others, however, a type of model does exist that captures time-varying and time-invariant effects. So-called panel data models capture both effects by analyzing data containing both cross-sectional and time-series data. These models have a number of appealing properties. First, as GLS models, they are robust to heteroskedasticity and autocorrelation. Second, they decompose the effort term into time-specific, building-specific and system-wide error components. Finally, by combining cross-sectional and time-series data, they tend to have higher statistical power than either cross-sectional or time-series models by themselves.

Specification of a general relationship between the various property characteristics and rents does not, in and of itself, constitute the statistical model. Panel data sets allow two basic types of statistical models, the fixed and random effects models. The data set for this analysis consists of multiple observations over time for a number of buildings, denoted $t=1, \ldots, T_i$ on each of $i=1, \ldots,$ N industrial buildings. As shown in Green (1993, pg. 466), the fixed effects model has the general form:

$$Y_i = \alpha_i + X_i\beta + \varepsilon_i\,, \tag{2}$$

where y represents the rent on building i. This model assumes a set of constant β values across all buildings and times. Each building, however, has its own intercept and error terms. The fixed effects model assumes the intercepts capture all variations across buildings.

Although the fixed-effects model is relatively simple to understand and implement, it does not admit time-invariant regressors due to perfect collinearity with the intercepts. Since most building characteristics are time invariant, the fixed effects model is inappropriate for this study.

Balestra and Nerlove (1960) and Fuller and Battese (1974) show, however, that estimation of a two-way random effects (variance components) model is possible. The random effects model assumes only one intercept for the entire regression, but allows up to three sources for the variance: a building-specific error, a period-specific error and a system-wide error. The general specification of the two-way random effects model is:

$$Y_{it} = \alpha + \beta' x_{it} + \varepsilon_{it} + u_i + v_t\,, \tag{3}$$

where:

$$\begin{array}{llll}
E[\varepsilon_{it}]=E[u_i]=E[v_t]=0, & & & \\
E[\varepsilon_{it}u_j]=E[\varepsilon_{it}V_s]=E[u_j\mathrm{v_t}]=0 & & & \text{for all } i, j, t, s, \\
\mathrm{Var}[\varepsilon_{it}] = \sigma_\varepsilon^2, & \mathrm{Cov}[\varepsilon_{it}, \varepsilon_{js}] = 0 & & \text{for all } i, j, t, s, \\
\mathrm{Var}[u_i] = \sigma_u^2, & \mathrm{Cov}[u_i, u_j] = 0 & & \text{for all } i, j, \\
\mathrm{Var}[v_t] = \sigma_v^2, & \mathrm{Cov}[v_t, v_s] = 0 & & \text{for all } t, s.
\end{array}$$

The term u_i represents the i^{th} building's error term and v_t represents the period-specific error. The breakdown of the total variance into building-specific, time-specific and system-wide components provides interesting insight into the market structure.

The exact form of the model estimated below is:

$$\begin{aligned} rrent_{it} = {} & \alpha + grsf_{it} + grsf_{it}^2 + ceil_{it} + ceil_{it}^2 + poff_{it} + poff_{it}^2 + age_{it} + age_{it}^2 + \\ & nddr_{it} + nddr_{it}^2 + ngdr_{it} + ngdr_{it}^2 + rail_{it} + spr_{it} + subocc_{it} + \\ & submarket\ location_{it} + net\_emp_{it} + \varepsilon_{it} + u_i + v_t\,, \end{aligned} \tag{4}$$

with the variables defined in Exhibit 1.

Exhibit 1
Summary Statistics

Variables	Definition	Mean	Std Dev.	Min.	Max.	No. of Cases
RENT	Rent per sq. ft	3.3533	.9031	1.200	8.000	11268
RRENT	Real rent per sq. ft (cpi adjusted)	2.9991	.8187	1.016	7.593	11268
GRSF	Gross rentable sq. (00s)	625.0900	610.2200	100.000	4980.000	11268
CEIL	Ceiling height in ft	18.3220	3.9634	10.000	36.000	11268
POFF	Percentage office space	13.5880	7.2523	.000	39.000	11268
AGE	No. of years since construction	14.7330	9.0388	.167	72.720	11268
NDDR	No. of dock high doors	7.1397	9.0452	.000	80.000	11268
NGDR	No. of ground-level doors	2.8657	6.9281	.000	80.000	11268
RAIL	Dummy (1,0) for rail availability	.2202	.4144	.000	1.000	11268
SPR	Dummy (1,0) for sprinkler system	.4603	.4985	.000	1.000	11268
SUBOCC	Percent submrkt occupancy	87.5740	5.1839	47.400	100.000	11268
NET_EMP	Annual change in net employment (00s)	265.5300	300.7300	−195.000	808.000	11268
LOC 1	Dummy (1,0) for submrkt 1	.0043	.0651	.000	1.000	11268
LOC 2	Dummy (1,0) for submrkt 2	.0375	.1901	.000	1.000	11268
LOC 3	Dummy (1,0) for submrkt 3	.0639	.2446	.000	1.000	11268
LOC 4	Dummy (1,0) for submrkt 4	.1370	.3439	.000	1.000	11268
LOC 6	Dummy (1,0) for submrkt 6	.0033	.0572	.000	1.000	11268
LOC 7	Dummy (1,0) for submrkt 7	.0162	.1264	.000	1.000	11268
LOC 8	Dummy (1,0) for submrkt 8	.0045	.0671	.000	1.000	11268
LOC 10	Dummy (1,0) for submrkt 10	.0177	.1317	.000	1.000	11268
LOC 11	Dummy (1,0) for submrkt 11	.0192	.1371	.000	1.000	11268
LOC 12	Dummy (1,0) for submrkt 12	.0279	.1646	.000	1.000	11268
LOC 14	Dummy (1,0) for submrkt 14	.0248	.1557	.000	1.000	11268
LOC 15	Dummy (1,0) for submrkt 15	.0198	.1393	.000	1.000	11268
LOC 16	Dummy (1,0) for submrkt 16	.0025	.0498	.000	1.000	11268
LOC 17	Dummy (1,0) for submrkt 17	.0788	.2695	.000	1.000	11268
LOC 18	Dummy (1,0) for submrkt 18	.0894	.2853	.000	1.000	11268
LOC 19	Dummy (1,0) for submrkt 19	.0256	.1578	.000	1.000	11268
LOC 20	Dummy (1,0) for submrkt 20	.1243	.3299	.000	1.000	11268
LOC 21	Dummy (1,0) for submrkt 21	.0143	.1187	.000	1.000	11268
LOC 22	Dummy (1,0) for submrkt 22	.0081	.0895	.000	1.000	11268
LOC 31	Dummy (1,0) for submrkt 31	.0069	.0829	.000	1.000	11268
LOC 32	Dummy (1,0) for submrkt 32	.0081	.0895	.000	1.000	11268
LOC 33	Dummy (1,0) for submrkt 33	.0624	.2419	.000	1.000	11268
LOC 34	Dummy (1,0) for submrkt 34	.0136	.1157	.000	1.000	11268
LOC 36	Dummy (1,0) for submrkt 36	.0083	.0905	.000	1.000	11268
LOC 38	Dummy (1,0) for submrkt 38	.0137	.1161	.000	1.000	11268
LOC 42	Dummy (1,0) for submrkt 42	.0167	.1281	.000	1.000	11268
LOC 43	Dummy (1,0) for submrkt 43	.0104	.1014	.000	1.000	11268
LOC 44	Dummy (1,0) for submrkt 44	.1363	.3431	.000	1.000	11268
LOC 46	Dummy (1,0) for submrkt 46	.0048	.0691	.000	1.000	11268

Data and Dependent Variable Specification

Industrial warehouse rent data was provided by M/PF Research Inc., the major real estate information service in Dallas/Fort Worth. The data consists of quoted industrial rents in the Dallas/Fort Worth metroplex during the fourth quarter 1989 through the fourth quarter 1993. M/PF surveys industrial building owners and obtains information regarding rents, vacancy and other property-specific information.

The sample consists of quoted rents for 848 industrial warehouses in the metroplex. The data set is unbalanced; not every building owner provided information in every quarter. Each building has a minimum of six observations (quarters), with many having the maximum of seventeen observations. For the entire data set, the average number of observations per building is 13.28, yielding 11,268 total observations.

In addition to quoted rents, each observation includes certain physical, submarket and general economic variables. The physical characteristics include total building square feet, i.e., the total contiguous leasable square feet in the building, percentage of office space in the building, the ceiling height in the warehouse, the number of dock high doors, the number of grade level doors, the presence of rail, the presence of sprinkler systems, and the age of the property.

Dummy variables are specified for each submarket defined by M/PF Research Inc. and serve as a proxy for location. M/PF identifies a total of forty-six industrial submarkets; eight submarkets are not in Tarrant or Dallas County and because of missing observations are not included in the database. Three other submarkets, numbers 13, 40 and 41, do not contain any observations. An additional six submarkets contained less than 1.5% of the sample, and because of difficulties with estimation associated with panel data, are not included. The final sample consists of the remaining twenty-nine submarkets. Changes in prior year non-agricultural employment (*net_emp*) serve as a proxy for general economic/market conditions. Exhibit 1 presents the descriptive statistics of the data set.

Empirical Results

Before running the random effects model, an extension of the Bruesch-Pagan LM test (Green, pg. 485) was estimated to check the appropriateness of the model. This test compares the random effects model to a pooled OLS regression model. The LM-statistic is constructed from the residuals of a pooled OLS regression. The exact form of the test statistic is:

$$LM = \frac{NT}{2}\left[\frac{1}{T-1}\left[\frac{\sum_i\left(\sum_t e_{it}\right)^2}{\sum_i\sum_t e_{it}^2}-1\right]^2+\frac{1}{n-1}\left[\frac{\sum_t\left(\sum_i e_{it}\right)^2}{\sum_i\sum_t e_{it}^2}-1\right]^2\right]. \tag{5}$$

This statistic is distributed χ^2 with two degrees of freedom under the null hypothesis that the pooled OLS model is the correct model specification. The LM-statistic for this data is 44,155, indicating the random effects model as the appropriate model relative to OLS.

Given that the random effects model is indicated, this model was estimated. The results are presented in Exhibit 2.

The model explains 38.24% of the pooled variation in rents. Of the variance components, the estimated $\sigma_\varepsilon{}^2$ was .081031, the estimated $\sigma_v{}^2$ was .154851, and the estimated $\sigma_u{}^2$ was .349924. Clearly the property-specific ($\sigma_u{}^2$) and time-period-specific ($\sigma_v{}^2$) differences account for the builk of the rent variations.

Of the significant physical characteristics, squared ceiling height, the number of grade high doors, percentage of office space squared, and the squared age are positive. Percentage of office space, ceiling height, age, the square of the number of grade high doors, and the presence of a sprinkler system are negative. Gross square feet squared, although statistically significant, effectively has a coefficient of zero, and thus has no economic impact. The major economic indicator, change in net employment, is positive and significant.

The linear term for ceiling height indicates that for each additional foot of ceiling height the annual real rent is reduced by $.10945 per square foot. This result is consistent with Ambrose's (1990) findings of a $.29 decrease in rent for each additional foot of ceiling height. Ambrose indicated that this result is consistent with true warehouse space being less costly on a per square foot basis. The square term, however, is positive, indicating that for each additional foot of ceiling height there is an additional increase in the rental rate of $.0019528. These terms imply that ceiling height negatively impacts rents for all buildings in the sample. Based on these coefficients, the relationship between rent and ceiling height is given by:

$$\frac{\partial rent}{\partial CH} = -.01095 * CH + .00195 CH^2 . \tag{6}$$

The second partial of rent with respect to ceiling height is:

$$\frac{\partial^2 rent}{\partial CH^2} = -.01095 + .00390 CH . \tag{7}$$

This second partial indicates that for ceiling heights of less than 28.08, rents decrease at an increasing rate when ceiling heights are increased, and that they decrease at a decreasing rate when the ceiling height is above 28.08 feet.

An increase in the percentage of office space in the building results in a decrease in real rents. Economically, the linear term implies that a one percentage point increase in the office space results in a $.0062 per foot per year increase in real rents for the building. The partial derivative of rents with respect to percent office space is:

$$\frac{\partial rent}{\partial Poff} = -.0062 * Poff + .0010 * Poff^2 . \tag{8}$$

Thus, the second partial with respect to office space is:

$$\frac{\partial^2 rent}{\partial Poff^2} = -.0062 + .0020 * Poff . \tag{9}$$

Exhibit 2
Random Effects Panel Data Model: Dependent Variable = Real Rent

Variables	Definition	Coeff.	Std Error	*T*-Ratio
Constant	Intercept	4.76200	.38500	12.370**
GRSF	Gross rentable sq. ft (00s)	.00015	.00009	1.555
GRSFSQ	Sq._Gross rentable sq. ft (00s)	−.00000	.00000	−2.193**
CEIL	Ceiling height in ft	−.10945	.03724	−2.939**
CEILSQ	Sq._Ceiling height in ft	.00195	.00092	2.127**
POFF	Percentage office space	−.00621	.00329	−1.883*
POFFSQ	Sq._percentage office space	.00101	.00007	12.900**
AGE	No. of years since construction	−.06526	.00381	−17.109**
AGESQ	Sq._yrs since construction	.00062	.00006	9.565**
NDDR	No. of dock high doors	−.00221	.00552	.415
NDDRSQ	Sq._No. of dock high doors	.00004	.00011	.410
NGDR	No. of ground-level doors	.02067	.00673	3.070**
NGDRSQ	Sq._No. of ground-level doors	−.00032	.00013	−2.478**
RAIL	Dummy (1,0) for rail availability	.06004	.05868	−1.023
SPR	Dummy (1,0) for sprinkler system	−.10764	.05511	−1.953*
SUBOCC	Percent submrkt occupancy	−.00080	.00061	−1.320
NET_EMP	Annual change in net employment (00s)	.00017	.00002	8.173**
LOC 1	Dummy (1,0) for submrkt 1	1.21290	.31710	3.825**
LOC 2	Dummy (1,0) for submrkt 2	.41143	.12290	3.348**
LOC 3	Dummy (1,0) for submrkt 3	.04937	.09332	.529
LOC 4	Dummy (1,0) for submrkt 4	.27627	.08172	3.381**
LOC 6	Dummy (1,0) for submrkt 6	.37239	.34170	1.090
LOC 7	Dummy (1,0) for submrkt 7	.09521	.16820	.566
LOC 8	Dummy (1,0) for submrkt 8	−.59008	.30120	−1.959*
LOC 10	Dummy (1,0) for submrkt 10	.03640	.17560	.207
LOC 11	Dummy (1,0) for submrkt 11	−.24937	.14690	−1.697*
LOC 12	Dummy (1,0) for submrkt 12	−.40158	.12390	−3.242**
LOC 14	Dummy (1,0) for submrkt 14	.02936	.13830	.212
LOC 15	Dummy (1,0) for submrkt 15	.52493	.14560	3.606**
LOC 16	Dummy (1,0) for submrkt 16	2.11770	.41480	5.106**
LOC 17	Dummy (1,0) for submrkt 17	.38434	.09326	4.121**
LOC 18	Dummy (1,0) for submrkt 18	.35156	.08358	4.118**
LOC 19	Dummy (1,0) for submrkt 19	.78078	.13960	5.591**
LOC 21	Dummy (1,0) for submrkt 21	.39087	.16520	2.366**
LOC 22	Dummy (1,0) for submrkt 22	.33630	.24650	1.364
LOC 31	Dummy (1,0) for submrkt 31	−.14567	.24660	−.591
LOC 32	Dummy (1,0) for submrkt 32	−.07169	.22350	−.321
LOC 33	Dummy (1,0) for submrkt 33	−.10097	.10240	−.986
LOC 34	Dummy (1,0) for submrkt 34	−.34468	.15340	−2.234**
LOC 36	Dummy (1,0) for submrkt 36	−.26246	.24610	−1.066
LOC 38	Dummy (1,0) for submrkt 38	.06807	.18010	.378
LOC 42	Dummy (1,0) for submrkt 42	.49397	.16610	2.975**
LOC 43	Dummy (1,0) for submrkt 43	−.28035	.18790	−1.492
LOC 44	Dummy (1,0) for submrkt 44	−.03156	.08064	−.391
LOC 46	Dummy (1,0) for submrkt 46	−1.04920	.26080	−4.022**

Adj R^2 38.24%
Lagrange Multiplier Test 44155

*significant at the 10% level; **significant at the 5% level

This indicates that rents decrease at an increasing rate until approximately 3.10% of the building is devoted to office space. At approximately 6.20%, the net effect of increasing office space becomes positive.

The building age variable is negative and significant indicating that real rents per square foot decrease by $.0653 each year based on age alone. This result suggests that real rents must increase by $.0653 per year in the market to offset the impact of age on a building. The squared term for age has a positive coefficient of .0006. Jointly these terms imply that age has a negative impact for all reasonable levels of age in the sample. These terms imply that rents decrease at an increasing rate until the building reaches an age of 52.6 years at which point rents continue to decrease but at a decreasing rate. The average building in this sample has an age of 14.73 years, indicating a corresponding $.83 reduction for the average building in real rent per square foot relative to a new building.

The presence of a sprinkler system reduces rents by $.10764 per square foot. The addition of a dock level door has no impact on real rents. The grade level doors coefficient, however, is positive and significant, indicating that a marginal grade level door increases rents by $.0207. The squared term has a negative and significant coefficient of −$.0033. The summary data indicate that the average building has a total of 2.87 grade level doors.

The industrial rental market adjusts positively to general economic conditions as indicated by the sign on the net growth in the non-agricultural employment variable. This result is consistent with most other rent studies. That is, increases in prior year net growth in non-agricultural employment are associated with increases in real rents.

In addition to variation due to physical and economic conditions, rents vary across submarkets. The dummy variable for submarket 20 (Garland) is the base case. This is one of the larger submarkets in terms of total buildings, with net absorption for the first half of 1993 at 69,600 square feet. The majority of the space is warehouse with limited office space. Five submarkets (8, 11, 12, 34, and 46) have significantly lower rents than submarket 20. All other submarkets had real rents equal to or significantly higher than this submarket. The highest rents are in submarket 16 (North Irving) where rents are on average $2.12 higher than rents in Garland. The lowest rents are in submarket 46 (Southeast Tarrant County), where rents are on average $1.05 less than in Garland. The submarket occupancy coefficient was insignificant.

The above results have some interesting implications for participants in the industrial warehouse market. Based on this data set, bigger buildings are not necessarily able to command higher rents. Gross square feet was not significant (at least at the 10% confidence level), and ceiling height had a negative coefficient. As Ambrose (1990) pointed out, renters of industrial space tend to be smaller firms that demand smaller, standard-sized space, while purchasers of industrial space tend to be larger firms that demand larger, specialized space. The data here tend to support that hypothesis. The negative coefficient on ceiling height may well be a signal that non-standard properties must yield a discount to attract tenants. Further, the insignificance of the dock level doors coefficient coupled with the positive coefficient on grade level doors also supports this idea. It is reasonable that a firm that uses less warehouse space would not need as extensive a distribution network. As a result, it might not benefit as much from dock level doors and, in fact, this type of firms may place a premium on grade level doors.

Summary and Conclusions

This paper provides the first empirical analysis of the determinants of pooled variation in industrial rents. A random effects model is employed to analyze data from 848 buildings for up to seventeen quarters. Under the two-way random effects model, real rents are positively related to changes in prior year net employment, and the number of grade high doors. Rents are negatively impacted by the age of the building, the ceiling height, percent office space, and the presence of a sprinkler system. The results indicate that rents are significantly impacted by physical characteristics, location and general market conditions. Additionally, there is evidence to suggest that the relationship between physical characteristics and rents is nonlinear.

The results support Ambrose's hypothesis that renters of industrial space tend to be smaller firms that demand smaller, standard-sized space. The results provide evidence that the market does not reward larger structures with higher real rents per square foot. As a result, developers and investors would appear to be best served by building/purchasing smaller, standardized structures.

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