A transactions-based real estate index: is it possible?

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Summary

This paper examines both practically and statistically the possibility of creating a transactions-based real estate price index similar to the well-known stock and bond indices. While the necessary methodology is available, differences in the real estate asset (and hence in the markets in which it trades) are shown to prohibit the development of such an index even under 'ideal' circumstances. First, in an informationally inefficient market, it is not in the best interest of most decision-makers to engage in the kind of complete disclosure needed to produce an accurate index. Second, even with complete disclosure, the number of transactions needed statistically to adjust for property differences substantially exceeds the number of quarterly transactions in most markets. While the empirical work supporting these conclusions is based on US data, the authors believe that similar constraints exist in most of the world's major markets and that investment professionals will be forced to work with less than ideal real estate proxies in constructing the global mixed-asset portfolio.

Keywords: real estate indexes, performance measurement

1. Introduction

Since global society first developed a surplus (savings), there has been a need to invest, and as the world became more complicated, a related need to monitor investment performance. Since real estate is the oldest (and internationally the most common) form of wealth, it naturally follows that investors seek to track its performance. Today, in most developed countries, government departments monitor housing and agricultural prices while securities firms monitor the prices of publicly traded mortgage instruments. However, the housing and farm price series cannot be purchased in the market while most of the mortgage series report a performance more similar to fixed income than equity investment. As investors seek to monitor the performance of their equity real estate investments and efficiently diversify across asset classes, they seek an equity real estate measure as comparable as possible to the commonly quoted stock and bond indices (both foreign and domestic).

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There is a series of contenders for the role of real estate proxy in investor's asset allocation models. Taking the US as an example, the most well known are the NCREIF Real Estate Performance Report and returns from Prudential’s PRISA portfolio. Both are widely reported measures of appreciation and income returns to large portfolios of investment grade real property, but for both, quarterly property values are estimated using appraisal techniques which have been shown to provide 'smoothed' return series. The ultimate effect of this smoothing is to reduce standard deviations of returns and impart bias of indeterminable direction on correlation coefficients. The combination of these two measurement errors leads researchers to question whether informed asset allocation decisions can be made using appraisal-based returns.

The problem in constructing return series for real estate is that properties simply do not trade on a frequent basis, so that prices representing a 'meeting of the minds' cannot be regularly observed within this asset class. Since identical financial assets trade frequently, these prices are available and holding period return calculations can be made using actual transactions. In real estate, this is not the case (i.e. the same or an identical property does not trade every quarter), so alternative methods of constructing a return series from market transactions must be developed.

This research defines an appropriate methodology which involves using an hedonic pricing model to derive a true transactions-based real estate index. The basic technique identifies and prices attributes of the property and is in widespread use in the housing literature and in business decision-making in general. An indexing paradigm is then shown which can be utilized to convert the results of the hedonic pricing model to an index which measures changes in value. The Charlotte, North Carolina industrial market provides the field data to test the feasibility of these technologies. With the methodology fully specified and all possible data extracted from the test market, we proceed to answer the underlying question – is a transactions-based real estate index possible?

The analysis proceeds in several sections. The first section provides a brief discussion of the existing real estate return series which have been used in studying portfolio performance. Next, the methodology for a true transaction-based property performance index is presented. This section includes a brief literature review of the few hedonic pricing models for income producing properties, and a discussion of the methodology employed in estimating prices for the industrial sample. The technique used for developing and testing a price index from the hedonic estimates is also presented in this section. The data base of Charlotte industrial properties is then described and the pricing variables explained. The problems experienced in collecting data for the transactions prices are presented in the various footnotes. From this technical and empirical foundation, 'ideal situation' confidence intervals are developed and examined from a 'credibility in performance evaluation' perspective. Conclusions and implications are provided in the final section.

2. Literature review focusing on currently available real estate return indices

As pointed out by Melnikoff (1984), quantification of equity real estate returns came of age with the movement of institutional investors, particularly pensions funds, into real estate equities in the 1970s. Zerbst and Cambon (1984) and Sirmans and Sirmans (1987) provide comparisons of the alternative return series, while Conroy et al. (1986) demonstrate how these numbers can be used in a simple portfolio model.

1In PRISA, dollars move into and out of the fund based on 'unit values'.
Recently, more substantial portfolio work has been done by Hartzell et al. (1986, 1987). This work confirms previous expectations about the inflation hedging ability of equity real estate, but calls into question naïve diversification across property types and regions.

While most of these studies provide useful information, they are flawed in three critical ways:

1. They are idiosyncratic, i.e. using data from only one or a few investment managers or they are not property specific, i.e. they are averages which smooth returns.
2. They are based not solely on current period actual sales, but on appraised values which rely on 'comparable' sales which often span several reporting periods.
3. They focus on capital markets theory ignoring the real estate asset class unique feature: that it trades as a series of local markets.

Moving from the real estate investment literature in general to return indices specifically, there is a series of major return indices currently available to the investor. We suggest them as alternatives/supplements, and today's best decisions probably result from a combined use of several of the measures. Figure 1 briefly presents the available return series.

Miles et al. (1989) develop a 'transaction driven' set of real estate returns using sales from the NCREIF data base. However, this work is totally ex-post concluding with the fourth quarter of 1986, i.e. it is not an ongoing index. More importantly, while their returns are constructed for various property types, they are not disaggregated to the municipality level. Hence their work cannot be used as an ongoing performance evaluation tool where specific location is a critical variable.

Clearly, there are a large number of alternative return and performance measures. However, for purposes of making informed investment decisions concerning performance evaluation or the inclusion of real estate in mixed asset portfolios, none of the series can be compared to financial assets on a true transactions basis.

3. A transaction-based property performance index

The new index developed here is based on a two iteration approach. The first step utilizes information from actual sales to determine which characteristics of value explain variation in prices across sales of a particular property type in a given local market. The second step formulates the price index using information from the first step. The first step produces a homogeneous product (e.g. the price of a square foot of industrial space in Charlotte) while the second constructs the index from changes in the price of this homogeneous product.

3.1. Model specification

Model specification begins with a review of relevant literature and a related determination of the appropriate characteristics of value for the estimation process. The identification of appropriate variables is critical because it serves as the guideline for data requests from the relevant participants in the test market and because the variability of the measures of these characteristics of value will determine the size of the confidence intervals developed in Section 5.

The underlying notion for the first stage model in the price index formulation is evolved from hedonic pricing models, where coefficients are estimated to determine contributions to total value or rent provided by particular property attributes. The general model that has been used in commercial property hedonics is
Fig. 1. Sources of Real Estate performance measures

A. The longest running series is the Real Estate Investment Trust (REIT) report published by the National Association of Real Estate Investment Trusts (NAREIT). While the underlying shares of beneficial interest could be purchased in the market, the shares represent claims to portfolios of mortgage, equity and hybrid REITs so they are not a true equity real estate benchmark. Further, the returns are not property specific and collectively they suffer from traditional underpricing of closed-end mutual funds.

B. The quarterly NCREIF Real Estate Performance Report is the most quoted measure of institutionally-owned equity real estate. It is a property specific total return index, but the values are based on appraisals (and hence are both smoothed and lagged) and the properties involved vary from quarter to quarter. (See Miles et al. 1989.)

C. The Coldwell Banker vacancy report has the advantage of being current and market specific (i.e. by city), yet vacancies are not a perfect measure of value, particularly with the increasing incidence of free rent and other tenant concessions. Further, the Coldwell Banker composite series is unweighted and the cities included vary from quarter to quarter. (A fuller discussion is available from Torto – Wheaton, a Coldwell Banker subsidiary.)

D. Several sources produce regional market models combining various supply and demand factors to estimate a particular market’s near and/or long term health. While these efforts are useful, they rely on secondary sources and are not always current with their focus oriented toward longer-term forecasting, not immediate reporting. (The most common producers of this type of data are major regional banks and University related Bureaus of Business Research.)

E. Over the last few years, various private data service firms have been developed which purport to directly survey current market activity on an ongoing basis. Some of the more ambitious are now bankrupt, (e.g. CRIS in Atlanta) while others such as REIS do not report transaction details.

F. A relatively new participant in the area is Standard and Poor’s National Real Estate Index, previously published by the Liquidity Fund, which reports transactions trends. The Index collects information from a wide variety of institutional sources and is very useful on a market-by-market basis. However, it is not possible to make adjustments for important value characteristics such as property quality, size, location within an urban area, etc, so that comparison of the index from quarter to quarter, and from market to market is not highly reliable.

G. Local governments have property tax and/or title information. However, the information is usually dated and the terms of sale usually poorly documented.

H. The national census reports several measures of property value but the information is always very dated and based on data collected by survey. This would be true of real estate related information provided by the Bureau of Labor Statistics and the Bureau of Economic Analysis as well.

I. Multiple Listing Services report sold properties in most major markets. While these data are timely, terms of sale are not available and the sample is incomplete, particularly for larger commercial sales.

Rent/square foot = \( f(X_1, X_2, \ldots, X_L, \beta_1, \beta_2, \ldots, \beta_L, \varepsilon) \) \hspace{1cm} (1)

where \( X_i \) (i = 1, 2, \ldots, L) are property characteristics, \( \beta_i \) are unknown parameters that must be estimated by some type of regression analysis method, and \( \varepsilon \) is an error term which is included in the specification in recognition of the fact that it is seldom possible to predict the dependent variable perfectly for any particular property. We use general functional notation in Equation 1, recognizing that the most frequently used functional form in the empirical literature is the linear form. (The hedonic literature that we reviewed also considers log linear forms and a Box–Cox approach that includes both the linear and log linear forms as special cases. See Clapp (1980); Brennan, et al. (1984); Cannaday and Kang (1984); and Hough and Kratz (1983).)

The limited number of commercial studies that have been undertaken in the past focus on office properties, and only in a few metropolitan areas. There is no consensus in these studies
concerning which of the independent variables are most appropriate in terms of explanatory power. Further, the surveyed studies attempt to explain rental rate variation, and not actual prices. The functional form which is 'best' varies across the studies, so perhaps the market sampled determines functional form. In short, the literature offers inconclusive evidence on the appropriate functional form, as well as the appropriate set of independent variables.

3.2. The appropriate hedonic model

The methodology used in the first step of the price index construction is similar, though of necessity not identical, to that utilized in the surveyed studies. The primary differences arise from the use of the entire building as the unit of observation with the change in price per-square-foot leading naturally to a price change index. The most important logistical consideration for deriving the transactions-based price index is the estimation of the coefficients of value. A large group of independent variables must be collected from several sources in the surveyed market. The data collection process must be thorough and accurate (and hence time-consuming) with information being provided on the following groups of variables: locational characteristics \((L)\), structural characteristics \((S)\), financial characteristics \((F)\), time-date of sale \((T)\), where \(L\) is the relevant locations parameters for each property in the local market including such information as census tract, square feet of similar space within 'X' miles or blocks, deriving times, etc. \(S\) is the age, number of floors, amenities, prestige proxy, GLA per tenant, etc. and \(F\) is the number of tenants, expected NOIs, vacancy levels, original lease length, weighted average number of months left on lease, types and terms of leases (percentage rents, escalations, net versus gross, etc.), lease guarantees, etc.

Rewriting the model, the first stage of the index construction is the estimation of the following equation:

\[
P/\bar{P} = f(L, S, F, \gamma; \mu)
\]

where \(L, S,\) and \(F\) represent the groups of variables described above, \(\gamma\) represents a vector of unknown regression coefficients, and \(\mu\) represents an error term. The dependent variable (the sales price) is adjusted for time using the CPI. \(^3\) (General functional notation is again used to indicate that a variety of forms should be tried using the Box-Cox methodology.)

The first step of the process is to adjust reported sales price for seller financing, extra land, and other characteristics just as in any hedonic model. Such adjustments to sales price are relatively straightforward using a strict present value criteria to value all non-market features. For example, the present value difference between the seller financing and 'market' financing, the market value of any excess peripheral land, and other factors which would

\(^3\)Final model specification depends on the availability of data in the sampled market as well as the determination of appropriate value characteristics for each property type. In all cases, thorough and accurate data collection is essential since unwarranted outliers can cause disastrous results in a regression framework. These particular parameters were selected based on the factors which proved significant in previous hedonic work and the researcher's ability to measure the parameters in the Charlotte market.

\(^4\)Ideally, there would be enough sales each quarter so that the values of the independent variables could be established from sales in the preceding quarter alone. Since the average number of sales-per-quarter is seven, several quarters must be aggregated to obtain sufficient sample size. Such aggregation requires price level adjustment of the dependent variables since without such adjustment the change found in this methodology would put all of the impact of inflation from the mid-point of the estimation period to the end of the current period in the most recent quarter. With price level adjustment and the assumption of stable betas over the estimation period, the change measure which is subsequently developed properly picks up only the current quarter's appreciation.
reduce the reported sales prices. This adjusted price is divided by useable square feet (not rentable, which varies with leasing strategy) to obtain the homogenous pricing element—the adjusted prices per useable square foot in a local market at time $t$.

3.3. The price index

Given the model estimated in the first stage, several potential avenues exist to derive the objective, the price index, Hedonic price indices in the housing literature use the typical house in the market area surveyed, and price the house by multiplying reference values for the typical home by the estimated coefficients in the first stage hedonic model. This generates an estimate of value, usually across MSAs, which is then used in other capacities (e.g. studies of supply and demand, house price inflation, depreciation, etc).

Adjusting to the current situation, and assuming data availability, we estimate the values of the independent variables over a four quarter period. These are the underlying data for the first stage estimation, and generate estimates of the $\gamma$s in Equation 2. In the subsequent quarter, actual transactions are surveyed to measure the characteristics of value for properties which have sold. The measures of the characteristic variables are then multiplied by the estimated first stage coefficients in the following way to generate expected price per square foot:

$$P_{t}^{\text{sf}} = f(L, S, F, \gamma)$$

where $\gamma$ is the vector of estimated coefficients, $P_{t}^{\text{sf}}$ is expected price per square foot, and the other symbols are as previously defined.\(^{4}\)

The difference between the actual observed sales price (in the fifth quarter) and the estimated expected sales price (from the $\gamma$s estimated in the preceding four quarters) is the change in the value over the quarter, or

$$\Delta P = P_t - P_t^E$$

where $\Delta P$ is change in price, $P_t^E$ is the price expected in period $t$ from Equation 3 above and $P_t$

\(^{4}\)For purposes of this test, data on the variables listed were collected on all industrial property transactions in Charlotte for the period from January 1983 to 31 December 1985. In addition to the hedonic model discussed above, the characteristics are valued directly from local scaling. In the latter case, rather than measure observable proxies for each major characteristic (i.e. location, structure, and lease), local experts provided a relative ranking. While this method introduces considerable subjectivity, it is potentially superior in its ability to capture market expectations, and subjectivity is partially controlled by providing examples for the scaling. Regression analysis (using the Box-Cox transformation to determine the appropriate functional form) provides coefficient estimates for the primary characteristic of value in the equations below:

$$P_{t}^{\text{sf}} = f(RLQ, RCQ, RTQ, RLPQ, V, T, \sigma; w)$$

where $RLQ$ is the relative location quality (1–10), $RCQ$ is the relative construction quality (1–10), $RTQ$ is the relative tenant quality (1–10), $RLPQ$ is the relative lease parameter quality (1–10), $V$ is the percent vacancy at date of sale, $T$ is time or date of sale, $\sigma$ is a vector of coefficients, and $w$ is an error term. The logic of the first four variables is straightforward. Vacancy rates serve as a proxy for lease-up risk and the present value of expected cash flow shortfall during the lease-up period.

Logic similar to Equation 3 is used to generate a price expectation using the intuitive scaling model,

$$P_{t}^{\text{sf}} = f(RLQ, RCQ, RTQ, RLPQ, V, \hat{\gamma}, \sigma)$$

where all symbols are as defined above, and $\hat{\gamma}$ is the vector of estimated coefficients.
is the actual price observed in period $t$. This change in value is obtained for each of the surveyed properties that sold in time $t$. An index of the change in value is then obtained by weighting each of the price changes by property square footage to obtain a size-weighted index change.\footnote{In words, $P_t^f$ is the price that would have been appropriate given all available information in the period prior to the index period, whereas $P_t$ is the actual price in the index period. The difference then is the change in price over the index period.}

### 3.4. Implementing the index

The quality of the index greatly depends on the quality and quantity of data employed in the estimation process. Estimation of the hedonic equation requires four quarters of data. For the Charlotte test, information on all known sales of industrial properties was collected for the period spanning from the first quarter of 1983 through the fourth quarter of 1985. Using this information, Equation 3 can be estimated to provide the $\gamma$ coefficients (for each four quarter period) to be used in the second step.

In the first quarter of 1984, all transactions are surveyed, and value characteristics extracted. These value characteristics along with the $\gamma$ estimates from the first step (for the first four-quarter period), are multiplied as in Equation 3 to generate the proxies for expected price per square foot for each of the sales $P_t^f$. Given these values and the observed actual transaction price, the change in price to be used as the input to the price index is derived.

Weighting to get a MSA-wide price change for each property type can be done in many ways. In this research, weighting is done on a size basis, but could also be done on either a value or equally-weighted basis. The MSA price change index is

$$TP_t = \frac{\sum_{i=1}^{I} P_t \cdot sf_i}{\sum_{i=1}^{I} sf_i}$$

where $i = 1, \ldots , I$ represents the properties surveyed in the fifth quarter, and $TP_t$ is the total weighted price. Taking this weighted price as a percentage of the total expected price per square foot of the properties surveyed in the fifth quarter gives a percent change. Starting at the level of 100 in the fourth quarter of 1983, this percentage can be applied to generate a new index value for the first quarter of 1984.

To update the index, the first stage estimation is performed using the second quarter of 1983 through the first quarter of 1984. The new indexing period for which all transactions and value characteristics are surveyed is the second quarter of 1984. Using the same process as defined to calculate $TP_t$ above, a new percentage price change per square foot is derived to update the value index. This type of rolling regression is repeated in each subsequent quarter to generate a time series of index values and the price appreciation component of total return index.\footnote{While an estimate of value is clearly being used (the expected price in time $t$), it is drawn from actual sales and compared to an actual sale. The NCREIF index compares two estimates both based on comparable sales which typically span multiple measurement periods.}

\footnote{This price change index could be combined with the income component of the NCREIF Index to obtain a total return index. However, since most of the variance in the returns would be expected to come from price change, analysts might choose to simply compare this index with corresponding price change indices for stocks and bonds.}
4. Data collection

The application of this index construction technique requires an extensive amount of data and thus close cooperation with the local real estate development and brokerage communities in the subjective market. Charlotte, NC industrial property was selected due to its relative homogeneity and simplicity. Charlotte is a growing distribution centre and thus has more industrial transactions than comparable size cities. Further, given the extensive local contacts of the authors in this market, it was felt that collection of data would be a relatively inexpensive and simple task at least relative to similar efforts in other markets.²

4.1. The Procedure

Property specific data were collected on all sales over the 12 quarter period in the Charlotte industrial market. The selection of industrial properties theoretically reduced the proliferation of descriptive variables, because industrial properties have fewer qualitative variables to quantify and fewer quantifiable variables to collect.

The properties used in the database were limited to industrial properties valued over $500,000 on county tax assessment records. This value was arbitrarily selected to limit the range of properties to those of institutional investment grade and size. This $500,000 cut off was applied to all publicly recorded industrial transactions between 1983 and 1985. A real estate data collection firm (REDI data) was used to differentiate properties by their usage. Properties zoned Industrial, with secondary classifications of either warehouse, manufacturing, or research laboratory were included. Using these criteria, relevant sales of 23, 48 and 80 properties were reported in 1983, 1984, and 1985, respectively. Charlotte tax records indicated many of the variables that would potentially be incorporated into the regression model, and the remaining variables that were deemed relevant in Section 3 were collected through site inspections of each property.

Beyond data collection problems on the independent variables,² there were significant problems encountered in obtaining complete specification of the dependent variable. A few properties were reclassified after visual inspection and several 'sales' turned out to be corporate transfers resulting from mergers, interfamily transfers at death, etc. In general, industrial brokers in Charlotte were simply not willing to provide information beyond a general selling price. Further, only half of the industrial transactions went through a major developer or broker in the area. For the transactions-based model to be indicative of general

²Clearly Charlotte industrial property is easier to model than several other markets. Thus a positive test in Charlotte might not imply a universally applicable model, but a negative test in Charlotte would be more generalizable.

²The qualitative characteristics for the intuitive scaling approach (see footnote 4) were given a numerical value on a scale from 1 to 10, with a '5' being half as good as a '10', and overall subjectivity being reduced by the establishment, before site inspection, of standards necessary to achieve minimum ratings. For example, the variable 'functionality' was defined within parameters which included dock high loading, ceiling height, concrete in truck turn arounds and drops, and size of truck access areas. The final list of qualitative variables was

(1) Quality of landscape;
(2) Functionality;
(3) Design aesthetics;
(4) Tenant quantity;
(5) Geographic quality zone: this is a relative locational variable in which regions of the city were ranked by brokers in the Charlotte Market.
market performance, any and all non-market financial characteristics are a necessary adjustment to the dependent variable in Equation 4. It is clear to the researchers that the collection of information on 'price adjustments' requires far more than an appraiser 'calling for comparables'.

Of the 81 usable transactions over the 1983–1985 period in Charlotte, only 12 verified sales prices, i.e. with necessary adjustments, were obtained after 15 months of effort and, at least initially, a great deal of goodwill on all sides. Clearly, 12 observations are not sufficient to use in any type of sophisticated multivariate analysis. The list of independent variables exceeds the number of observations which means no degrees of freedom in the data. The only recourse would be drastically to reduce the number of explanatory variables which runs counter to our preliminary findings that more rather than fewer variables are needed to capture price difference across properties.

Because of the small number of multivariate studies that have been done using transactions data, it is difficult to judge the sample size that would be necessary to achieve results that possess a high degree of accuracy. Given the experience of Miles et al. (1989), we feel that a sample size of between 50–100 is needed to obtain enough diversity in the explanatory variables so that significant t statistics for regression coefficients can be obtained; and even significant t statistics may not be enough to insure the tight confidence intervals required if the derived index is to be useful in performance evaluation.

5. The confidence interval issue

While the foregoing description of data accessibility problems casts a rather dark cloud over the effort, an examination of the 'what if' question brings the probability of a reliable transactions-based index to near zero. The exercise presented below uses the actual Charlotte data on the independent variables to try and give a realistic answer to the 'what if' question, i.e. what if the true sales prices (with all necessary adjustments) had been obtained on the majority of the Charlotte sales.

Assume in a hypothetical 'best case' that for 50 of the Charlotte properties full detail on sales transactions had been forthcoming for the four quarter estimation period from the local investment community (recall the true number was 12 over the whole of the 3-year period). Assume further that this data, when fit to a simple two variable pricing model, produced an \( R^2 \) of 0.90. Finally, assume that five new properties sell in the next quarter and that full information is available on all five. As the following calculations from the Charlotte database indicate, the resulting price appreciation index would be expected to have a wide 'confidence

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10 As a reference, note how many 'empty cells' are usually found in the typical commercial appraiser's in-house description of comparables.
11 Techniques for determining sample sizes necessary to achieve statistical significance are well known in the sampling survey literature (see Cochran, 1977). Most results pertain to simple univariate models. In multivariate regression models, there is no simple formula that can be used to determine the sample size needed. The typical suggestion is to examine the standard errors of regression coefficients obtained in similar studies. Miles et al. (1989) is the most similar analysis to the one proposed and we base our estimate at a sample size in the 50 to 100 observation range of these earlier estimations.
12 \( R^2 \) of 0.90 was the best result obtained in any of the pricing equations in the Miles et al. transactions-driven work using 5–9 independent variables including audited quarterly operating performance which would clearly never be available in a true transactions-based effort like the subject Charlotte study.
interval' that the measure would be highly unreliable as a tool for either performance evaluation or use in portfolio diversification planning.

Fifty of the Charlotte properties are randomly selected and it is assumed that the location and functionality measures explain 90% of the variance in the known sales price. The hypothesized relationship is

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \]  
(7)

where \( Y \) is sales price, \( X_1 \) is distance to interstate, \( X_2 \) is functionality, \( \beta_0 \) is the intercept, \( \beta_1 \) is the coefficient on distance to interstate, \( \beta_2 \) is the coefficient on functionality and \( \varepsilon \) is the error term which is assumed to have mean zero and variance \( \sigma^2 \). Only two independent variables are used in this illustration to simplify the mathematics.

From a 50 property random sample of the Charlotte database, the descriptive statistics for the two independent variables are

<table>
<thead>
<tr>
<th></th>
<th>( X_1 ) (Interstate)</th>
<th>( X_2 ) (Functionality)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.57</td>
<td>7.10</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.67</td>
<td>2.05</td>
</tr>
<tr>
<td>Variance</td>
<td>2.78</td>
<td>4.20</td>
</tr>
<tr>
<td>Covariance</td>
<td>-0.83</td>
<td>-0.83</td>
</tr>
</tbody>
</table>

The variance of functionality is higher because it is measured on a 1–10 scale while distance to interstate is either adjacent, within a mile or greater than 1 mile, i.e. a 1–3 scale. The covariance between the two characteristics of value is negative (−0.83) which is expected since the modern structures tend to be located to interstate access points.

The preceding table reports the actual descriptive statistics on the two independent variables. We use this information along with the chosen \( R^2 \) of 0.90 to calculate a set of mutually consistent values for coefficients, standard errors and \( t \) statistics for coefficients, and disturbances variance. This information can then be used to generate confidence intervals as Appendix A demonstrates.

The standard errors and \( t \) statistics are

\[ t_1 = \frac{\hat{\beta}_1}{SE\hat{\beta}_1} = \frac{-1}{0.6058} = -1.6507 \]  
(8)

\[ t_2 = \frac{\hat{\beta}_2}{SE\hat{\beta}_2} = \frac{1}{0.4928} = 2.0292 \]  
(9)

The \( t \) statistic for \( \hat{\beta}_1 \) (coefficient of distance to interstate) is significant at the 10\% level while the \( t \) statistic for \( \hat{\beta}_2 \) (coefficient of functionality) is significant at the 5\% level. These values are indicative of a well defined pricing equation. If we choose \( \hat{\beta}_0 = 20 \) the prediction equation is

\[ \hat{P} = \$20/\text{square foot} - 1 \text{ (interstate variable)} + 1 \text{ (functionality variable)}. \]  
(10)

In the observation period (the current quarter), we observe the \( X \)'s for the five sold properties and can easily calculate a weighted average predicted sales price per square foot. (Most importantly, we can estimate a variance for this prediction.) The price appreciation is then the difference between the actual weighted average sales price (which is assumed known)
and the predicted price. In the prediction period the weighted average $X$s were interstate 1.4, functionality 7.3 for these five properties (taken randomly from the remaining Charlotte database; i.e. the original 81 less the 50 already chosen) yielding a predicted price of $25.9/\text{per square foot}$ ($20-1.4+7.3=25.9$). Assuming the actual weighted average sales price this quarter was 26.3, the appreciation is $26.3 - 25.9 = 0.4$, divided by $25.9 = 1.54$.\(^{13}\)

The standard error of the predicted sales price can be determined by noting that:

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2$$

which means that

$$\text{Var}(\hat{Y}) = \text{Var}(\hat{\beta}_0 + X_1^2 \text{Var}(\hat{\beta}_1) + X_2^2 \text{Var}(\hat{\beta}_2)$$

$$+ X_1 X_2 \text{Cov}(\hat{\beta}_1, \hat{\beta}_2)$$

\(^{(12)}\)

The variances and covariances of $\hat{\beta}_1$ and $\hat{\beta}_2$ are determined from the covariance matrix of $X_1$ and $X_2$ and the calculated value of $\sigma^2$. (See Appendix 1.) We will assume a variance of 100 (standard deviation 10) for $\hat{\beta}_0$ since this produces a $t$ statistic of 2 (i.e. significant at the 5% level).

This yields a variance of 113.9574 or a standard deviation of 10.6751. Thus the 95% confidence interval around the predicted sales price of $25.9/\text{per square foot}$ is 5.0 to 46.8.\(^{14}\)

This produces a related confidence range on quarterly appreciation from:

$$\frac{26.3 - 5.0}{5.0} \text{ to } \frac{26.3 - 46.8}{46.8}$$

$$+ 426.0\% \text{ to } -43.8\%$$

Obviously this range provides little confidence when working with issues of performance evaluation or portfolio diversification.

Even if the variance of the constant term were zero (i.e. it were known with certainty or could be suppressed with no loss of efficiency) the standard deviation of $\hat{Y}$, would be 3.7359 and the confidence interval 18.6 to 33.2. Inserting these values in the appreciation index we have:

$$\frac{26.3 - 18.6}{18.6} \text{ to } \frac{26.3 - 33.2}{33.2}$$

$$+ 41.4\% \text{ to } -20.8\%.$$  

which is still very large implying an unreliable index.

Seeking an index with a small enough confidence interval to be useful, one faces an interesting 'catch 22' situation. The variances and covariances of the $\hat{\beta}$s are inversely related to the variance and covariances of the $X$s. This means more variability in the $X$s results in more accurate $\hat{\beta}$s for use in the prediction equation, and therefore a more accurate prediction.

\(^{13}\)For the comparative purposes, the appraisal based NCREIF warehouse index showed total appreciation of 6.1% for all four quarters of 1984 so 1.54% for one quarter is in the reasonable realm.

\(^{14}\)Standard deviation of 10.675 times $1.96$ provides the 95% confidence interval around the predicted price of $25.9/\text{ft}^2$.

$$25.9 + 10.675 (1.96) = 46.8$$

$$25.9 - 10.675 (1.96) = 5.0$$
equation. Unfortunately, the values for the Xs in the prediction period also affect the variance of the predicted sales price — as they increase, the variance in the predicted value increases. Of course as the sample size increases, all problems are mitigated as the variances of the βs are driven to zero. However, the number of properties sold in any quarter in any city is hardly likely to approach ‘a very large number’ in the near future.

6. Conclusions and implications

Several conclusions can be drawn from this effort, which is motivated by a genuine need for a transactions-based index (see Sections 1 and 2). There is a well-recognized methodology which is adaptable for application to various sectors of the real estate market (see Section 3). Since a significant amount of data is required, it makes sense to test the model in a local market, so that expense is limited, verification of sample variables can be easily performed. Overall, the technique is reasonable, and the project is testable. However, the base elements needed to construct the index are (1) expansive and potentially not cost effective to collect, (2) not publicly available information, and (3) contrary to the day-to-day operations and thought processes of the individual market players.

There is no incentive for brokers or individual investors to provide the information (primarily the transaction price and all the related financial terms of a transaction). Brokers, developers and individual investors are predominantly micro-oriented. The larger, national and internationally oriented companies — the Crow Companies, Coldwell Bankers, Richard Ellis etc. — are rarely sufficiently dominant in a market to the point that a centralized collection could be organized in conjunction with one of these major players. This micro perspective creates a short-term outlook in which the benefits of transactions-based index in terms of enhanced long-term institutional investment are lost.  

An additional characteristic of real estates markets that serves as a barrier to the establishment of the index is the practical perspective of real estate as an informationally inefficient market, with significant amounts of information required beyond the observable structural and locational characteristics. Brokerage is basically a knowledge business, where knowledge includes who needs what space, who wants to purchase what set of attributes, who wants to invest in what type of product, who is paying what, and many other aspects of real estate information. This is probably even more true in Europe (excepting England) and Asia than in our test case in North America. It is against the nature of any such market to give away this knowledge. Given the number of players in institutional real estate at present, from insurance firms to investment banks, it is doubtful that any national or international organization could sell a local market player on the idea that he should give up his knowledge, which is his basis to compete in the local market, to a potential rival in the marketplace.

13Traditional concepts of vacancy and average rents are useful tools for both the local players and national players, and indices based on these measures have been more easily established. Importantly, these are one or two variable measures that are relatively easily defined and modestly comparable across markets.

The cost, in time and dollars, to the network of individuals in local firms to contribute to a transaction-based performance index intuitively does not equal the return to them which may accrue by bringing an incremental increase in institutional investment into the market. (This assumes that institutional investors are not presently waiting for such an index to exist before they enter a given market.) That end would be a primary incentive for local market players to participate in collection of the necessary transaction information, and the lack of that incentive seriously questions the viability of a transactions-based index.
Even if the market participants could be encouraged to provide accurate detailed transaction data, the prospects for a true transactions-based market index would not be good. The 'catch 22' described in Section 5 suggests that the number of transactions needed to obtain a sufficiently tight confidence interval on the predicted sales price would vastly exceed the number of sales in any given market. Again, there are more transactions in North American markets, so the conclusions hold even more strongly in Europe and Asia. Without tight confidence intervals on the predicted price, the resulting index would not be useful for either performance evaluation or strategic diversification analysis. ¹⁶

In summary, although there is great intuitive appeal to establishing a Transactions-Based Real Estate Index, the practical reality is that it won’t be established in the foreseeable future. If the industrial segment of the Charlotte market doesn’t even come close to 'confering an index' with the effort described in this paper, it is unlikely that today’s institutional investors will soon see a transactions-based commercial real estate index for all real estate markets. ¹⁷

Appendix 1. Calculation of the confidence interval

The first step is to note that the relationship between the true variance of \( Y \) (the sales price) and the other variables is

\[
\text{Var}(Y) = \beta_1^2 \text{Var}(X_1) + \beta_2^2 \text{Var}(X_2) + 2\beta_1\beta_2 \text{Cov}(X_1, X_2) + \sigma^2
\]

or

\[
\text{Var}(Y) = A_x + \sigma^2
\]

where the \( \beta \)'s and \( X \)s are as previously defined and \( A_x \) has the implied definition.

Population \( R^2 \) for the above regression shown in Equation 7 is

\[
R^2 = 1 - \frac{\sigma^2}{A_x + \sigma^2}
\]

Solving for \( \sigma^2 \) yields:

\[
\sigma^2 = A_x \left( \frac{1 - R^2}{R^2} \right)
\]

This implies that if we choose \( R^2 \) and pick values for \( \beta_1 \) and \( \beta_2 \), we can calculate the appropriate \( \sigma^2 \) since we observe the sample variances and covariances for \( X_1 \) and \( X_2 \) from our sample of actual properties in the Charlotte data base. After \( \sigma^2 \) is determined, standard formulas can be used to determine the standard errors for the chosen \( \beta \)s and the corresponding \( t \) statistics can be calculated.

Choosing \( \beta_1 = -1 \) and \( \beta_2 = 1 \) with \( R^2 = 0.90 \) and substituting into the above formulas yields a \( \sigma^2 = 0.96 \). This value can then be used to determine standard errors for \( \beta_1 \) and \( \beta_2 \)

¹⁶In Section 5, we assume a best case with only two independent variables explaining 90% of the variation in price. If more variables were needed to achieve such explanatory power, the increased multicollinearity would lead to higher standard errors and even larger confidence intervals.

¹⁷This being the case, it is possible that investors will take the 'leap of faith' described by Miles (1989) and use some combination of the indices described in Section 2 and the 'Transactions Driven Returns' produced by Miles et al. (1989) in their asset allocation models, or continue to arbitrarily adjust risk parameters for the real estate asset class to bring them more into line with intuition (See Hartzell, 1986).
using the basic ordinary least squares formulas, the inputs being \( \sigma^2 \) and the inverse of the covariance matrix of the \( X \)s.

The basic detail behind the calculations is shown below:

**Proposed Assumptions**

\[
Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon
\]

\[
\begin{align*}
R^2 &= R^2 \quad 0.9 \\
\hat{\beta}_1 &= -1 \\
\hat{\beta}_2 &= 1 \\
\hat{\beta}_0 &= 20 \\
\text{Var}(\hat{\beta}_0) &= 100
\end{align*}
\]

**From Charlotte Data**

<table>
<thead>
<tr>
<th>Mean</th>
<th>( X_1 )</th>
<th>( X_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.57</td>
<td>7.10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard deviation</th>
<th>1.67</th>
<th>2.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance</td>
<td>2.78</td>
<td>4.20</td>
</tr>
<tr>
<td>Covariance ( (X_1, X_2) )</td>
<td>-0.83</td>
<td></td>
</tr>
</tbody>
</table>

**Fact:**

\[
\beta_1^2 \text{Var}(X_1) + \beta_2^2 \text{Var}(X_2) + 2 \beta_1 \beta_2 \text{Cov}(X_1, X_2) + \sigma^2 = A_x + \sigma^2
\]

**Fact:**

\[
R^2 = 1 - \frac{SSE}{SST} = 1 - \frac{\sigma^2}{A_x + \sigma^2}
\]

**Fact:**

\[
\sigma^2 = A_x \frac{A}{R^2}
\]

**Solving:**

\[
\sigma^2 = 2.78 + 4.2 + 2 (0.83) \frac{0.1}{0.9}
\]

\[
= 8.64 (0.1111) = 0.96
\]

**Fact:**

\[
\text{Covariance} (\hat{\beta}) = (\hat{x}' \hat{x})^{-1} \sigma^2
\]

**Solving:**

\[
\text{Covariance} (\hat{\beta}) = 2.78 - 0.83^{-1} (0.96)
\]

\[
= 0.83 - 4.20
\]

\[
= \frac{1}{10.9871} 4.20 0.83 2.78 (0.96)
\]

\[
= 0.367 0.0725
\]

\[
= 0.0725 0.2429
\]

**Thus:**

\[
\text{Variance} (\hat{\beta}_1) = 0.367 \quad \text{Covariance} (\hat{\beta}_1, \hat{\beta}_2) = 0.0725
\]

\[
\text{Variance} (\hat{\beta}_2) = 0.2429
\]

\[
\text{SE} (\hat{\beta}_1) = \sqrt{0.367} = 0.6058
\]

\[
\text{SE} (\hat{\beta}_2) = \sqrt{0.2429} = 0.4928
\]

**Fact:**

\[
t = \frac{\hat{\beta}}{\text{SE}(\hat{\beta})}
\]

**Solving:**

\[
t_1 = -1/0.6058 = -1.6507
\]

\[
t_2 = 1/0.4928 = 2.0292
\]
A transactions-based real estate index

Fact: \[ \text{Var}(\hat{Y}) = \text{Var}(\hat{\beta}_0) + X_1^2 \text{Var}(\hat{\beta}_1) + X_2\text{Var}(\hat{\beta}_2) + X_1X_2 \text{Cov}(\hat{\beta}_1, \hat{\beta}_2) \]

Solving: \[ \text{Var}(\hat{Y}) = 100 + 1.57^2(0.367) + 7.1^2(0.2429) + 1.57(7.1)(0.725) \]
\[ = 100 + 0.9046 - 12.2446 + 0.8082 \]
\[ = 113.9574 \]

Solving: \[ \text{Std. dev. } (\hat{Y}) = \sqrt{113.9574} = 10.6751 \]

Solving: \[ \text{Confidence Interval (95\%) = } 25.9 \pm 1.96 (10.6751) \]
\[ = 5.0 \text{ to } 46.8 \]

(Var \( \beta_0 = 0 \))

Solving: \[ \text{Var } (\hat{Y}) = 13.9574 \text{ (see above)} \]

Std. dev. \( (\hat{Y}) = 3.7359 \)

Solving: \[ \text{Confidence Interval (95\%) = } 25.9 \pm 1.96 (3.7359) \]
\[ = 18.6 \text{ to } 33.2 \]

References


