4-1-2012

Cornell Real Estate Market Indices

Crocker H. Liu Ph.D.
Cornell University, chl62@cornell.edu

Adam D. Nowak Ph.D.
West Virginia University

Robert M. White Jr.

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Abstract
In this report, we introduce three new metrics to monitor real estate activity in the hotel market, as measured by transaction prices. The large hotel index records sales of hotels equal to or greater than $10 million, while the small hotel index covers the hotels selling for less than $10 million. The third metric is a repeat sales index (RSI) to track actual hotel transactions. All three indices are constructed quarterly using both the CoStar and Real Capital Analytics commercial real estate databases. The large and small hotel indices are constructed similar to the consumer price index (CPI). In contrast, the repeat sale hotel index is analogous to the retail concept of same store sales, except that it compares a series of sales of a particular hotel property over time.

Keywords
Cornell, commercial property index, repeat sales index, hedonics

Disciplines
Real Estate

Comments
Required Publisher Statement

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EXECUTIVE SUMMARY

This paper introduces three new metrics to monitor real estate transaction price changes in the hotel market. They are: a large hotel index (hotels equal to or greater than $10 million), a small hotel index (hotels less than $10 million), and a repeat sales index (RSI) for hotels to track actual hotel transactions. All three indices will be issued quarterly, based on data compiled by CoStar and Real Capital Analytics. The large and small hotel indices are similar in construction to the consumer price index (CPI), while the repeat sale hotel index is analogous to the retail concept of same store sales, as it compares the sales and subsequent sales of the same hotel over time. These measures provide a more accurate representation of the current hotel real estate market conditions than does the current practice of reporting the average transaction price in each time period, because the average price measure does not account for hotel quality in a given transaction. The major goals for these hotel indices are to provide benchmarks to gauge current hotel price movements and to allow for the comparison of hotel performance relative to other property types.
In this report, we introduce three new metrics to monitor real estate activity in the hotel market, as measured by transaction prices. The large hotel index records sales of hotels equal to or greater than $10 million, while the small hotel index covers the hotels selling for less than $10 million.  

The third metric is a repeat sales index (RSI) to track actual hotel transactions. All three indices are constructed quarterly using both the CoStar and Real Capital Analytics commercial real estate databases. The large and small hotel indices are constructed similar to the consumer price index (CPI). In contrast, the repeat sale hotel index is analogous to the retail concept of same store sales, except that it compares a series of sales of a particular hotel property over time.

1 While our dividing line for small and large is arbitrary, HVS also uses $10 million as the reference point in separating large transactions from small transactions. See for example, S. Mellen, “Hotel Transaction Activity Slows, Cap Rates Rise” HVS, January 2012.
We show that all three measures provide a more accurate representation of the current hotel real estate market conditions than does the current practice of reporting the average transaction price in each time period. The problem we see with average transactions is that the average doesn’t account for various quality levels of hotels. Instead, the quality of the hotels is averaged as well. Consequently, if the particular hotels that are sold in each period differ in quality, then it is difficult to ascertain whether a higher average price is the result of higher quality hotels being transacted or an indication of higher price appreciation for hotels of constant quality in a given period. This first report begins with data in the fourth quarter of 1995, as a baseline. The three indices provide benchmarks to gauge current hotel price movements, and they also allow for the comparison of hotel performance relative to other property types.

**What the Indices Measure**

All three indices are designed to measure price appreciation over time on a quarterly basis. We discuss the specific development of the indices in the technical appendix. In general, the change in the price from one quarter to the next is calculated as follows:

$$\text{Price Appreciation} = \left( \frac{\text{Price}_t - \text{Price}_{t-1}}{\text{Price}_{t-1}} \right)$$

(1)

For example, suppose that the price of our hotel is $110.811 million. It was previously purchased for $97.553 million. Thus, the price appreciation on this hotel is 13.59 percent (($110.811 - 97.553)/97.553 = .1359 \times 100$ percent).

**The Value of These Hotel Real Estate Indices**

We know of only three hotel real estate indices: the NCREIF hotel index (part of the NCREIF Property Index or NPI), which represents institutional grade hotel properties that trade in the property market; the National Association of Real Estate Investment Trusts (NAREIT) equity REIT hotel index; and the recently developed Baird/STR hotel securities index. The first two indices are total return indices, although the price appreciation and income components of the index are also reported, and the third index is a price appreciation index. While each of these indices has utility, we see the following limitations.

The NCREIF hotel index is based on appraised values rather than actual transaction prices. Appraised values are not only biased but also understate the volatility in returns, a phenomenon known as appraisal smoothing. Appraisal-based indices also are lagging indicators of movements in the real estate market. Another appraisal issue is "stale" appraisals. Although the appraised value is reported quarterly, it is well known that many of the properties are not actually reappraised each quarter. Beyond the issues related to appraisal, the NCREIF Hotel Index includes a growing, but still limited number of hotels. The number of hotel assets in the NPI has increased from six in 1982 to 70 in the second quarter of 2010.

With the advent of large commercial real estate transaction databases, such as those maintained by CoStar and Real Capital Analytics, it is now possible to construct price appreciation indices for hotels using actual transactions. Such transaction-based indices already exist for other commercial property types, but hotels have heretofore been omitted, because they have not been considered as core real estate. That view is diminishing, however, and hotels are becoming an increasingly attractive asset class for institutional investors, since hotels can enhance investment returns and reduce portfolio risk. With their daily room rate pricing and relatively low correlation to other property types, hotels provide diversification benefits within a real estate portfolio.

**Hedonic and Repeat Sales Indices: A Brief Introduction**

The challenge in creating price or value indices for commercial real estate is that every property is unique. Two basic methods exist to transform the heterogeneity of commercial real estate into constant quality relative to prices. These methods are the hedonic method and the repeat sales approach.

**Hedonic Index**

A hedonic pricing model assumes that the price of an item can be represented as a function of its attributes. The
Consumer Price Index (CPI) is an example of a hedonic index. The CPI is a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services, known as attributes. To implement a hedonic model for real estate, the transaction price is regressed on attributes such as square feet, number of stories, and other salient attributes to adjust for quality changes. Hedonic models in real estate were initially used in the analysis of housing markets. The best example of a hedonic index in commercial real estate is the NCREIF Transaction Based Index (TBI), together with its various property subindices, which do not include hotels. The NCREIF TBI index reflects the change in price for institutional grade commercial real estate. Alternatively, it represents a benchmark that a private equity real estate investor can use to compare against stock and bond indices.

From a hotel context, attributes include the number of units, age of the hotel, number of floors, and location. Each hotel has a distinct price arising from supply and demand conditions in the local commercial real estate market and from the hotel’s distinct collection of characteristics. In a hedonic framework, each hotel attribute has a market of its own and hence a hedonic price. For example, real estate analysts frequently discuss hotel transactions in terms of price per room (or per key). Extending this example, if we wanted to consider age relative to the price per room, the price per room is expected to diminish as the hotel ages, all other things (such as number of floors) remaining constant. At $10 million per transaction or more, our new large hotel hedonic index is designed for comparison against the NCREIF TBI index and property type subindices. Our small hotel index is designed for comparison against the price appreciation index for hotel REITs that primarily hold small hotels or for those investors considering what the portfolio impact is of including smaller hotels in their asset mix.

Repeat Sales Index (RSI)
Repeat-sales indices simply look at hotels that have sold more than once to measure the price change of a particular hotel over time. The repeat sale model is a variation of the hedonic method with the limitation that only hotels that sell more than once are used in constructing the index. Like the hedonic models, the first repeat sale model in real estate started with residential properties. The residential repeat sale index has come into prominence in recent periods with the commencement of tradable Case-Shiller indices, options and futures for which are traded on the Chicago Mercantile Exchange. The best example of a repeat sale index in commercial real estate is the Moody’s/REAL Commercial Property Price Index (CPPI) and its four property-type subindices developed at MIT and based on actual transaction data from Real Capital Analytics (RCA). Again, this index does not include hotels. The Moody’s/REAL CPPI index provides information that complements the MIT/NCREIF TBI. In contrast to the MIT/NCREIF TBI, the Moody’s/REAL CPPI does not contain only institutionally held properties, and consequently is a much broader index that is more representative of the entire commercial real estate market (both large and small properties) compared to the MIT/NCREIF TBI index. Recently, CoStar also introduced a set of repeat sale indices that are not, however, available for download as are the MIT indices.

The chief drawback of a repeat sales index is that properties that are frequently traded are not necessarily representative of hotels in general, and thus the index is not based on a random sample of all properties. A second limitation is that a property can be improved between sales, making it no longer strictly comparable. A third limitation, related to the first, is that the number of observed repeat transactions is small compared to the total number of sales transactions which is used to calculate the price index. Finally, the repeat sales index is also subject to constant revision, because hotels are continually being added to the base as they experience subsequent sales. This means that the estimate of the rate of hotel price appreciation between any two periods will continually be revised. This occurs in part because the prices of hotels whose “initial” sale is in the reporting period are not included in the estimation until a “repeat” sale occurs. Only then does the price appreciation of such hotels affect the estimate of the initial reporting period’s aggregate index level. Consequently, a repeat sales index value is always in flux. The hedonic price

7 According to the Bureau of Labor Statistics, the goods and services in the CPI are arranged into eight major groups as follows: (1) food and beverages (including wine and full service meals), (2) housing (actual or owner’s equivalent rent of primary residence and such expenses as fuel oil and bedroom furniture), (3) apparel (including jewelry), (4) transportation, (5) medical care, (6) recreation (including televisions, pets expenses, and event admissions); (7) education and communication; and (8) other goods and services (including tobacco products, personal services, and funeral expenses).


9 For details on the NCREIF TBI index please visit http://www.ncreif.org/tbi-returns.aspx. MIT initially developed the indices. NCREIF recently took over their production and reporting.

### Exhibit 1

**Types of real estate indices**

<table>
<thead>
<tr>
<th>Index</th>
<th>Type</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential (Price Index)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zillow.com</td>
<td>Hedonic</td>
<td><a href="http://www.zillow.com/local-info/">http://www.zillow.com/local-info/</a></td>
</tr>
<tr>
<td>Commercial (Price Index)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moodys/REAL Commercial Property Price Index</td>
<td>Repeat Sales</td>
<td><a href="http://mit.edu/cre/research/credl/rca.html">http://mit.edu/cre/research/credl/rca.html</a></td>
</tr>
<tr>
<td>NCREIF Property Index Returns (total return)</td>
<td>Appraisal</td>
<td><a href="http://www.ncreif.org/property-index-returns.aspx">http://www.ncreif.org/property-index-returns.aspx</a></td>
</tr>
</tbody>
</table>

### Exhibit 2

**Median sale price and volume of transactions for hotels under $10 million, 1995–2011**

Indices overcome some of the shortcomings of the repeat sale index.

Despite these shortcomings, the repeat sales index is widely used in practice and remains a viable approach to estimating national hotel price appreciation. We present our new repeat sale hotel index to allow our readers the opportunity to make the appropriate comparison with other property types given the prominence of the Moody’s/REAL CPPI. In summary, although both the hedonic method and the repeat sale approach are already used in commercial real estate, hotels have been omitted. We believe it’s appropriate to create a hotel index for each of these benchmarks, given the commercial real estate (CRE) industry’s primary focus on the four major property types. Exhibit 1 gives a recap of
some of the more widely recognized residential and commercial real estate indices.

**Data**

We obtained hotel transaction prices for both the hedonic price indices and the RSI from the CoStar and Real Capital Analytics databases.\(^{11}\) We exclude all data for which there was no sale price. We also omit any bulk sales and portfolio sales and any other transactions where the price is allocated, appraised, or based on street talk. For our hedonic price indices, we exclude any transaction for which no information was given on the number of units, the age of the building, or the number of floors. Hence, the repeat-sale transactions are not necessarily a subset of transactions used for constructing the hedonic price indices since the RSI only requires the sale prices of the same hotels that have sold repeatedly over time.

CoStar and Real Capital Analytics are the largest sources of commercial real estate information, with the transaction data verified from market participants including buyers, sellers, and brokers. We should also note that Real Capital Analytics (RCA) is a Cornell Center for Real Estate and Finance (CREF) industry partner. The data from CoStar and RCA complement each other since some transactions are reported by one but not by the other. To verify the location of the property, we use its address but also confirm each property's latitude and longitude. This is necessary since the address or the geographic coordinates could be incorrect for a particular property.

The number of observations associated with the construction of each index is as follows: for the large hotel hedonic price index, 2,100; for the small hotel hedonic price index, 7,083, and for the repeat sale index, 4,024. The median sale price and volume of transactions for hotels under $10 million starting in the first quarter of 1995 and ending in the third quarter of 2011 is shown in Exhibit 2, while Exhibit 3 provides the same information for the large hotel transactions. An examination of these two figures shows that an analyst can use either the transaction volume or the median sale price to get a sense of the direction of the hotel real estate market. This suggests that even when prices are not reported for hotels, the mere fact that a hotel has been sold gives an indication of the state of the hotel real estate market. Not surprisingly, although there are more transactions involving small hotels in each time period, a comparison of Exhibits 2 and 3 tells a similar story for both small and large hotel transactions. The submarkets for both types of hotels

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\(^{11}\) CoStar (http://www.costar.com/); Real Capital Analytics (http://www.rcanalytics.com/).
### Exhibit 4

Values for the Cornell hotel indices

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Hedonic Index: Four-quarter Moving Average</th>
<th>Repeat Sales Index</th>
<th>Quarter</th>
<th>Hedonic Index: Four-quarter Moving Average</th>
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</table>
began to trend upwards starting in the third quarter of 2002 and reached a peak around the second quarter of 2007 in terms of transaction volume, after which transactions started to decline until the latter half of 2009. Major hotels started to trend upwards during the second half of 2009 while smaller hotels continued their downward spiral, signaling a flight to quality during the world economic panic. Large hotels appear to turn downward at the start of 2011.

Results
Exhibit 4 reports the small hotel hedonic index, the large hotel hedonic index, and the repeat sale index series. Readers who are interested in obtaining the hedonic index and repeat sale index for the four main property types—office, industrial, retail, and apartments—can use the URL listed in Exhibit 1 to download the appropriate data.

The price performance of large hotels relative to small hotels using the hedonic method is shown in Exhibit 5. Although the small hotel hedonic index has greater volatility, both high price hotels and smaller price hotels tended to move together. As we mentioned above, the two series diverged starting in the fourth quarter of 2009 with hotels involved in high price deals increasing in price while the smaller hotels continuing to decline. This trend is consistent with the observation by Suzanne Mellen of HVS that “Transaction activity (for major hotel transactions) has resumed, and has been increasing its velocity since the last quarter of 2009. Once occupancy levels bottomed out in late 2009, investors began to build the expectation of a rebound in hotel earnings into their acquisition pricing.”

During the fourth quarter of 2009, hotel mortgage interest rates for loans made by insurance companies which report to the American Council of Life Insurers also started to decline from their high in the second quarter of 2009 (the prior peak for hotel interest rates occurred in the first quarter of 2000). The dichotomy in prices that we observe is also similar to that reported by Real Capital Analytics for commercial real estate in general. In particular, RCA noted that while the Moody's/REAL CPPI National Aggregate Index continued to decline during the latter half of 2009, large properties in major markets turned upward over the same period (e.g., in New York, Washington, D.C., San Francisco, Los Angeles, Boston, and Chicago). Lawrence Yun, chief economist for the National Association of Realtors, also made a similar observation in comparing the Green Street Advisors Price Index to the REAL CPPI National Aggregate Index noting that “early chasers are looking only at class-A properties in prime locations.”

13 http://economistsoutlook.blogs.realtor.org/2011/10/12/commercial-property-prices/
Average and Median RSI/RevPAR = 2.35

Sources: Cornell Center for Real Estate and Finance, PKF Hospitality Research (Hotel Horizons), CoStar, Real Capital Analytics
Exhibit 6 shows the Cornell repeat sales hotel price appreciation index. The RSI reached its peak in the third quarter of 2007, declined until the third quarter of 2009, and then turned upward one quarter prior to the hedonic price index for major hotel transactions. The upward momentum in the latter half of 2009 is consistent with the 2009 Year in Review Hotel Trends report published by Real Capital Analytics, which noted that “While activity is down significantly versus previous years, hotel transactions picked up toward the end of the year with a large cluster trading between $50,000 and $150,000 per key.”

One of the most important and heavily watched metrics for hotels is the revenue per available room (RevPAR), a multiple of which is used to link the value of a hotel to its revenue. Exhibit 7 displays the relationship between RevPAR taken from the PKF publication Hotel Horizons and our repeat sales hotel index. Even though the RevPAR multiple is not a straight line, since hotel values are typically based on net free cash flows rather than total revenues, the graphs in Exhibit 7 show that the RevPAR multiple fluctuates primarily between 2 to 3 over time (except at the start of our index), with the mean and median RevPAR multiple equal to 2.35 over our estimation period.

At the start of this paper, we stated that our new indices are useful to gauge the performance of hotels relative to commercial real estate indices that exclude hotels, namely, the MIT/NCREIF TBI and the Moody’s/REAL CPPI. We compared our hotel indices to these two benchmarks, with the results shown in Exhibits 8 and 9. Exhibit 8 presents the relationship between the MIT/NCREIF TBI index and the Cornell Large Hotel Hedonic Index. Although hotels are considered a more specialized property type, it is interesting that large hotels have a 77.5-percent correlation with institutional grade real estate, even though hotels are typically perceived as a riskier property type. The moderate correlation between large hotels and the TBI (non-hotel property types in aggregate) confirms the perception that large hotels do provide portfolio diversification. Notice that since the fourth quarter of 2009, major hotels have exhibited a higher upward velocity relative to other types of commercial real estate. This is probably due to the shorter nature of hotel leases and reflects that hotels appear to be leading the recovery.

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15 Values are based on net operating income which includes other major profit centers such as spas, golf courses, and food and beverage whose impact on net income is not reflected in RevPAR.
16 We recalibrate our index to have a base value of 100 in 1995Q2 so that both our Large Hotel index and the MIT/NCREIF TBI initially start off at 100.
Similarly, Exhibit 9 shows the relationship between the Moody’s/REAL CPPI and our new Cornell repeat sale hotel index. Since the CPPI starts in the fourth quarter of 2000, we recalibrated our index to have a base value of 100 in that quarter. The two indices exhibit a similar pattern for many quarters—not surprising since all property types tend to move together to some extent due to common factors which have an impact on all real estate. Since the third quarter of 2009, however, the two indices appear to diverge, with the hotels outperforming core real estate. This again reflects hotels’ ability to change their “lease rates” quickly relative to leases on core real estate. As mentioned earlier, during a recovery, occupancy rates, average daily rates, and thus RevPAR are expected to steadily rise as the economic recovery gains strength.

Potential Applications of Indices
Our article has demonstrated several uses for our new, quarterly hotel indices. Like the CPI, we can evaluate the “average” price movements in the overall hotel market for large hotel deals and small hotels at different time periods while keeping the quality of the attributes constant. As we noted, the divergence of large hotels’ price appreciation from that of small hotels indicates a flight to quality, just as investors seek large cap stocks in preference to small cap stocks during times of crises. Our repeat sale index is useful for comparing deviations between the index and RevPAR, a proxy for hotel fundamental value. Where the index is greater than the traditional relationship with RevPAR this signals a potential bubble situation. Similarly, an analyst can compare the performance of our repeat sale hotel index to that of the Moody’s/REAL CPPI to observe the performance of hotels against that of other commercial real estate. Depending on the divergence in this relationship, one gains an early warning signal of either opportunities or rough weather ahead. Finally, the Cornell small hotel hedonic index can be used to measure the performance of underlying real estate to the stock performance of hotel REITs that invest primarily in smaller hotel properties to detect the possibility that the real estate is undervalued (or the REIT’s value does not reflect that of the underlying real estate). Lastly, our indices give investors an indication of whether and how to use hotels for purposes of portfolio diversification. Knowing the performance of hotels investors can determine how much to invest in hotel properties relative to other property types. Our new set of indices finally allows investors to address the question of how much weight to put into hotels relative to other property types.
Data Cleaning

Our data cleaning process for the hotel repeat sales indices follows the S&P/Case-Shiller procedure, which is designed to eliminate outliers. Outlier properties might influence the index away from a more accurate estimate of average property price appreciation rates. Such outliers include transactions wherein the property has undergone substantial renovation or deterioration as well as properties that have experienced exceptionally large or small appreciation rates relative to a normal range of appreciation rates (perhaps due to data-entry errors). For the hotel RSI, we exclude pairs where the first sale involved new construction and pairs with sales within six months of each other. We drop transactions with sale prices of less than a million dollars and also exclude pairs with more than 60 percent annual changes in price. The hotel price data used in the index starts in the first quarter of 1995.

Calculating a percentage change from the same quarter in the previous year controls for whatever seasonality may be present in the data. Annual rates of change typically are thought of as applying to a calendar year but in this report the annual rates that are reported would be measuring change over any twelve month period. In calculating the RSI, we exclude any hotel transaction that would generally involve a discount or might not have a market based selling price, including an assemblage, condo conversion, court appointed sale, distress sale, leasehold, partial interest transfer, redevelopment project, REO sale (that is, bank real estate owned), short sale, auction sale, bankruptcy sale, contaminated building, building in shell condition, bulk or portfolio sale, high vacancy property, exercise of option, ground lease (leased fee), ground lease (leasehold), and lease option, and also sales which included two or more properties. These types of sales are typically excluded in obtaining market comparables to value a property. International Valuation Standards defines market value as “the estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arm’s length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently, and without compulsion.” Thus, our transactions are representative of properties which meet those criteria.

Estimation Method

**Hedonic Price Index**

We use a form of the hedonic pricing model which assumes that the natural log of the selling price is a linear combination of attributes. Specifically

\[
\ln(p_{jt}) = X_j \beta + (1 - D_j)L_t + D_jH_t + \varepsilon_{jt} \quad (2)
\]

where \(p_{jt}\) is the sale price for hotel \(j\) sold at time period \(t\), \(X_j\) is a vector of location and physical attributes for hotel \(j\), \(\beta\) is a vector of attribute prices, \(D_j\) is equal to one if the sale price for hotel \(j\) at time \(t\) is less than $10,000,000, \(L_t\) is the price level for low-price hotels at time period \(t\), \(H_t\) is the price level for high-price hotels at time period \(t\) and \(\varepsilon_{jt}\) is an error term. Here, each time period corresponds to one quarter where the data set begins quarter 1 of 1995.

The vector \(X_j\) includes an intercept, the variable \(D_j\) described above, a binary variable equal to one if there is a previous transaction for hotel \(j\) in the data set, and the hotel’s age, number of units, number of floors, and square footage. These variables are included to control for the physical characteristics of the hotel.

In addition, to control for the hotel’s location, the vector \(X_j\) also includes binary variables for the District of Columbia and the 48 states for which we have transaction data.* That is, \(X_{jk}\) is equal to one if the hotel is located in state \(k\) and zero otherwise. The results indicate that the District of Columbia is the only location with a coefficient significantly different from zero at the 10-percent level of significance; however, F-tests indicate that at least one of the other location coefficients is significantly different from zero at the 1-percent significance level.

The variables \(L_t\) and \(H_t\) are used to estimate the hedonic price index over time. Binary variables are used to estimate the index values. These binary variables are equal to one if the hotel was sold at time period \(t\) and zero otherwise. In order to avoid perfect multicollinearity among the variables, the binary variable associated with Year 2000 quarter 1 is omitted. In addition, the time variables interact with the binary variables that indicate a low-price or high-price transaction. Because of this, \(L_t\) and \(H_t\) correspond to separate indices for low-price and high-price transactions.

Coefficients are estimated using least squares. After estimating coefficients, the index values are calculated using four quarter moving averages. Specifically, for time period \(t\), index values are calculated using

* No transactions were recorded in Alaska or Vermont.
where $\hat{\lambda}$ is the least squares coefficient for the low-priced hotels, and $H_{t-s}$ for the high-priced hotels. With this form, index values above 100 indicate that, after controlling for physical and location attributes, hotels are selling above prices in the first quarter of year 2000.

### Repeat Sales Price Index

The repeat sales index is computed using feasible generalized least squares (FGLS). There are N sale pairs used in the estimation. Each sale pair corresponds to the same-property sale at two different time periods. For each sale pair $j$, the following equation is estimated

$$\Delta p_j = \ln(p_{jt}) - \ln(p_{js}) = C_t - C_s + \varepsilon_j \quad (3)$$

Here, $p_{jt}$ is the sale price of property $j$ at time period $t$, $p_{js}$ is the sale price of property $j$ at time period $s$, $C_t$ and $C_s$ are the nationwide log index levels at time $t$ and $s$, and $\varepsilon_j$ is the error term associated with sale pair $j$. $E[\varepsilon_j^2]$ is assumed to be an affine function of the holding period $t-s$ which suggests FGLS estimation.

Initially, equation (3) is estimated using ordinary least squares (OLS) producing

$$\Delta p_j = \hat{C}_i - \hat{C}_s + \hat{\varepsilon}_j \quad (4)$$

Here, $\hat{C}_i$, $\hat{C}_s$, and $\hat{\varepsilon}_j$ are the OLS price levels and residuals. In order to more efficiently estimate the log index levels, a FGLS estimator is computed which takes into account the structure of $E[\varepsilon_j^2]$ Using the squared residuals, the following equation is estimated using OLS

$$\varepsilon_j^2 = \alpha + \beta(t-s) + w_j \quad (5)$$

Using the estimated coefficients, $\hat{\alpha}$ and $\hat{\beta}$, the sale pairs are then weighted proportionally to the variance of the error term, $E[\varepsilon_j^2]$. For each sale pair, the FGLS estimator of the log index levels is computed using the scaled sale pairs

$$\frac{1}{\sqrt{s_j}} \Delta p_j = \frac{1}{\sqrt{s_j}} (C_t - C_s + \varepsilon_j) \quad (6)$$

where $s_j = \hat{\alpha} + \hat{\beta}(t-s)$. The log index levels estimated from equation (6) are the FGLS estimates of the log index levels. These price levels are the minimum variance unbiased estimators. The index levels are computed from the log index levels by taking the exponents of the estimates and normalizing them so that the value in quarter 1 of Year 2000 is equal to 100. Since this index is a product of statistics it may contain estimation error. Given the number of repeat sale hotel transactions, there are not enough observations to produce a separate major hotel and small hotel repeat sale index.
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The CREF Report series is produced for the benefit of the hospitality real estate and finance industries by The Center for Real Estate and Finance at Cornell University

Jan A. deRoos, Executive Director
Jennifer Macera, Associate Director
Glenn Withiam, Director of Publications

Center for Real Estate and Finance
Cornell University
School of Hotel Administration
389 Statler Hall
Ithaca, NY 14853

Phone: 607-255-6025
Fax: 607-254-2922
www.cref.cornell.edu
ABOUT THE AUTHORS


Adam D. Nowak, Ph.D., is an assistant professor of economics at West Virginia University. He earned degrees in mathematics and economics at Indiana University–Bloomington in 2006 and a degree in near-east languages and cultures that same year. His thesis title was “Eigenvector Methods and Cointegrated Series.” Nowak taught an introduction to macroeconomics course and a survey of international economics at Arizona State. He was the research analyst in charge of constructing residential and commercial real estate indices for the Center for Real Estate Theory and Practice at Arizona State University.

Robert M. White, Jr., CRE, FRICS, is the founder and president of Real Capital Analytics, Inc., an international research firm that publishes the Capital Trends Monthly. Real Capital Analytics provides real-time data concerning the capital markets for commercial real estate and the values of commercial properties. A noted authority on the real estate capital markets with credits in the Wall Street Journal, Barron’s, The Economist, Forbes, New York Times, and Financial Times, he was named one of National Real Estate Investor’s “10 to Watch” in 2005, Institutional Investor’s “20 Rising Stars of Real Estate” in 2006, and Real Estate Forum’s “10 CEOs to Watch” in 2007. He spent 14 years in the real estate investment banking and brokerage industry and has orchestrated billions of commercial sales, acquisitions and recapitalizations. He was formerly a managing director and principal of Granite Partners LLC and spent nine years with Eastdil Realty in New York and London. White is a Counselor of Real Estate, a Fellow of the Royal Institution of Chartered Surveyors, and a Fellow of the Homer Hoyt Institute. A graduate of the McIntire School of Commerce at the University of Virginia, he is also a member of numerous industry organizations and a supporter of academic studies.

We wish to Professor Jack Corgel and Professor Jan DeRoos for constructive comments in the preparation of this professional paper. We also wish to thank Glenn Withiam for copy editing this paper.

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