

The Secular and Cyclic Behavior of “True” Construction Costs

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Abstract

Current construction cost indices typically are derived by applying national weights to local costs for materials and labor. In this study, construction cost indices are developed that are based on actual contractor tenders for projects. As such, they incorporate full variation in factor proportions, as well as factor costs, contractor overhead, and profit. Cost indices are produced for two product types, office and multi-family residential, in six different MSAs using F.W. Dodge project cost data from 1967 through the first half of 2004. Standard “hedonic” analysis is applied to control for variation in project scale and features to extract the true time trends in costs for each market. The findings indicated that real construction costs generally have fallen slightly over the last 35 years. In addition, no correlation is found between costs and building activity. Causal (IV) analysis implies that the construction industry is elastically supplied to local real estate markets, with any “excess” profits going to land and developer entrepreneurship. This is consistent with the traditional “urban land economics” literature.

This paper develops construction cost indices based upon the actual construction tenders for a very large number of building projects over the 1967–2004 period. Using these indices, two questions are examined. First, there has been much discussion over why the appreciation of most commercial real estate over the 35 year period has been actually slightly less than inflation (Geltner and Miller, 2004). The current paper finds that construction costs have behaved similarly during this time—generally increasing slightly less than overall economic inflation. Real estate markets are widely thought to be mean-reverting around replacement costs and thus to the extent that replacement costs are based mainly on the construction (as opposed to land) component—this paper provides an answer. The second question is to explore if there is a tendency for construction costs to rise cyclically during periods of major building activity. If this is the case, it could suggest that the construction industry is less than elastically supplied to local real estate markets. Whether this is due to inelasticity in the supply of materials and labor, or the whether contractors and construction firms are able to extract short run

profits, cannot be distinguished. In either case, however, inelasticity would cast some doubt on the time-honored axiom of modern urban economics that any excess returns go to land or entrepreneurship (Clemhout, 1981; and Blackley, 1999).

The analysis is made possible by using the records from the FW Dodge company covering 67,000 building projects in six chosen metropolitan areas, for two major types of buildings: low- to mid-rise office building and garden-type apartments. This is the first time this data has been used to assess cost trends, although Coleman and Gentile (2001) present interesting results about the construction process. With this database, hedonic cost equations are estimated for each market and property type that include several variables related to project scale, building features, and density of development. Yearly fixed effects are used to extract the time trends in these costs.

This approach is far broader than that used by several commercial suppliers of construction cost “indices” (ERN, 2004; and RS Means, 2004). These indices generally apply fixed weights to local variation in the costs of the major factors of production: labor and materials. In theory, this approach suffers from two omissions: first, factor proportions may and in fact should vary both cross section and over time with differences in factor costs and secondly, construction profit or overhead may vary cyclically to absorb some short run development profits.

The results of the analysis are quite pronounced. First, the yearly movement in construction costs is quite small—rarely more than 5%–10% when adjusting for inflation. In fact, the indices are quite smooth. In this regard they look quite similar over the 35 year study period to the factor cost indices of RS Means and ERN.

Secondly, over the longer run, there is a gradual trend wherein constant dollar costs have declined for both studied property types, in all but one of the six markets. This too is similar to the long run trends in the indices of the cost vendors. This may help to explain the observation that constant dollar office and apartment rents show no upward trend over a similar 35 year period (DiPasquale and Wheaton, 1992; and Wheaton and Torto, 1994).

Finally and perhaps most importantly, virtually no evidence is found that the construction cost indices vary with the level of building activity. A wide range of correlation tests is performed with different lags and there simply is no significant pattern. However, this might be the result of the complicated simultaneity issue suggested by Sommerville (1999). If building activity is negatively related to costs (construction demand) but costs are positively related to building activity (construction supply), then reduced form correlations could yield little. This idea is explored with an IV approach using local job growth, national interest rates, and inflation as demand instruments for building activity. The results are little different and this as a strong indication that the construction industry is supplied with almost perfect elasticity to local commercial real estate markets.

The paper is organized as follows. First, there is a discussion of the data and the selection of cities and building types. Second, the hedonic equation estimates are

provided along with the time trends in the data. These are then compared with other construction cost indices. Third, there is a comparison of the movement in costs to the yearly level of building activity data for each of the chosen property types. Finally, the paper closes with concluding remarks.

F.W. Dodge Construction Data

The data used in this analysis was made available by F.W. Dodge, a subsidiary of McGraw-Hill Construction. This proprietary data was used with their permission and is derived from the company's business of providing a "matching process" between developers and contractors. The former post requests for bids (from architectural plans to final interior finishing), the latter respond, and after the project is complete, F.W. Dodge assembles all the contracts into a "project file." From this, total project costs are derived. It should be mentioned that these total "bid" costs are then later followed up by a survey of "all in" costs that presumably covers cost adjustments or over runs.

For this study, six MSAs were selected: Chicago, IL; Phoenix, AZ; Denver, CO; Washington, DC; San Diego, CA; and Dallas, TX. Chicago and Washington, DC are traditionally considered more mature cities, while the others have exhibited consistently higher growth over the last 35 years. The Dodge company classifies projects into 25 categories. This paper examines two that were both very prevalent in the data, and in addition represent fairly uniform types of structures. This was low-rise office buildings (2–4 stories) and garden-type apartment properties. The data for these two types included total construction costs for over 80,000 projects. In addition to this project "filtering," limited descriptive information regarding frame or construction technology, number of stories, and floor area was also included. For apartments, the number of units was also known. The data for the Chicago, Dallas, and Washington, DC MSAs begins in 1967. Data for Phoenix and San Diego was available back to 1968, and data for the Denver MSA was only available back to 1969.

Of the 80,836 data points collected, approximately 4% were incomplete. Projects that lacked area, cost, or story information were removed from the sample. Data from projects under 2,000 square feet for multi-family and 10,000 square feet for office buildings or over .5 million square feet were also eliminated from the data set. The intent of the study is to develop a construction cost index representative of typical projects, so outliers at the extreme ends of the size spectrum were removed from the sample. The data was then segregated at the MSA and property level, providing twelve different sets of data. After this screening, the office sample size was reduced to 18,469 observations ranging between 1,937 and 3,857 observations per MSA. There were 42,340 apartment observations ranging between 3,777 and 12,259 observations per MSA (Exhibit 1).

It certainly is to be expected that construction costs per square foot will vary by project size, and in the case of apartments, project density (units/square foot).

Exhibit 1 | Number of Observations by Product Type and Location

| | Chicago | Dallas | Denver | Phoenix | San Diego | Washington, D.C. | Total |
|-----------|---------|--------|--------|---------|-----------|------------------|--------|
| Apartment | 12,259 | 3,777 | 3,356 | 5,943 | 9,301 | 7,704 | 42,340 |
| Office | 3,857 | 3,154 | 1,937 | 3,344 | 2,383 | 3,794 | 18,469 |

Number of stories is also often associated with greater foundation and structure costs. The frame type of the property was also included as potentially impacting costs. The F.W. Dodge data included twelve different frame classifications.

Code Frame Type

- 0 Alterations, non-building, etc. without framing
- A Load or Wall Bearing (no further description)
- B Steel
- C Wood
- D Concrete
- E Pre-Fabricated or Pre-Engineered
- F Other Described Framing Types
- G Unknown Framing Type (no description)
- H Steel and Concrete
- I Load or Wall Bearing and Steel
- J Load or Wall Bearing and Wood
- K Load or Wall Bearing and Concrete

For this study, records with the ‘0’ code were removed because they are alterations, and not new construction. Records that had unknown or hybrid frame types, classified as codes E–K, also were combined into one single “other” category. This was done because most of the structures fall into one of the first four classifications—load bearing, steel, wood, or concrete. Exhibit 2 displays the distribution of frame types by location and product type.

The construction cost data does not account for soft costs such as time delays, development, or legal fees. The cost data does cover engineering and architectural fees as those are part of the Dodge matching service. Of course it must be remembered that project specifications and building standards have changed over the years—in many ways not captured by the data. Properties today have improved HVAC systems, Internet wiring, and must follow generally more stringent building codes. All of these omissions generally mean that more recently built projects are “better” in many unmeasured ways. As such, the indices will be biased *upwards* over time. To build a property in 2003 that is actually comparable to one in 1967

Exhibit 2 | Frame Type by Location and Product Type

| MSA | Product Type | Frame Type | | | | | Total |
|------------------|--------------|-------------|-------|-------|----------|-----------|--------|
| | | Loadbearing | Steel | Wood | Concrete | Unk/Other | |
| Chicago | Apartment | 56.0% | 6.3% | 23.4% | 3.8% | 10.4% | 100.0% |
| | Office | 62.1% | 20.3% | 2.8% | 3.8% | 11.1% | 100.0% |
| Dallas | Apartment | 58.4% | 11.9% | 15.2% | 3.8% | 10.7% | 100.0% |
| | Office | 16.2% | 7.7% | 66.0% | 1.2% | 9.0% | 100.0% |
| Denver | Apartment | 52.6% | 24.6% | 4.9% | 6.4% | 11.6% | 100.0% |
| | Office | 40.2% | 18.8% | 25.7% | 4.6% | 10.7% | 100.0% |
| Phoenix | Apartment | 18.6% | 1.1% | 37.8% | 2.1% | 40.5% | 100.0% |
| | Office | 33.1% | 20.1% | 9.9% | 9.4% | 27.5% | 100.0% |
| San Diego | Apartment | 25.1% | 9.7% | 25.2% | 5.4% | 34.6% | 100.0% |
| | Office | 66.7% | 1.0% | 21.4% | 0.7% | 10.3% | 100.0% |
| Washington, D.C. | Apartment | 71.6% | 11.3% | 5.5% | 4.0% | 7.6% | 100.0% |
| | Office | 69.1% | 6.0% | 13.6% | 2.3% | 9.0% | 100.0% |

would likely cost less than that which is recorded for “measurably comparable” 2003 buildings.

Estimation of Hedonic Costs

Hedonic regression analysis has long been the favored means of rent and price analysis in the real estate market. After Rosen (1972), hedonic equations have been widely applied to many product differentiated markets (Brown and Rosen, 1982), including single family house prices (Palmquist, 1984), and then to commercial rents and prices (Wheaton and Torto, 1994). Hedonic regression has also recently been used to examine construction costs in the residential market by Somerville (1996).

There are several options that may be used in creating a hedonic regression model (Cropper, Deck, and McConnell, 1988). Both linear and semi-log models were examined in the current study in relation to *COST* and *COST/SF*. In past studies, semi-log models have produced the best results. However, there is debate as to whether *COST* or *COST/SF* as the dependent variable provides the best results. The former produces better fits, but the latter tends to have more normally distributed errors. Each of the different regression methods was tested and in this analysis, the model that produced the best statistical results in terms of parameter significance was a semi-log regression of *COST/SF*.

The semi-log regression model expresses the natural log of cost in nominal dollars divided by the total square footage of the project, $\ln(COST/SF)$, as a function of

the number of stories, units, total area, frame type, and year constructed. Alternative formulations using floor plate and stories as opposed to area and stories worked identically—as it should when the equation is in semi-log form. In this form, each independent variable in the equation has a percentage impact upon *COSTSF*, as opposed to a dollar impact, such as would be the case in a linear regression. For instance, if the coefficient for *UNITS* was .005, then each additional unit would increase *COSTSF* by .5%. Dummy variables were used to describe the year that the projects were completed. If the coefficient for the year 2000 was $-.22$, then all projects completed in that year would cost 22% less in nominal dollars than in the default year (2004 was chosen as the default year in this analysis). Load bearing was chosen as defaults for *FRAME*. The log linear model estimated is hence:

$$\begin{aligned} \text{Ln}(\text{COSTSF}) = & \alpha_0 + \alpha_1 \text{STORY} + \alpha_2 \text{UNITS} + \alpha_3 \text{AREA} \\ & + \sum \beta_i \text{FRAME}_i + \sum \beta_i \text{YR}_i \end{aligned} \quad (1)$$

Where:

COSTSF = Construction cost per square foot of building;

STORY = Number of stories;

UNITS = Number of units in the project (apartment regression only);

FRAME = Dummy variable for type of construction, steel frame, concrete, load bearing, or wood;

AREA = Square feet of building in 1000s;

YR_i = Dummy variable for each year; and

α , β = Estimated statistical parameters.

The results of the hedonic regression for the six apartment and office markets were quite significant statistically with R^2 values ranging between .64 and .86 for the apartment regressions and between .50 and .65 for the office regressions. These regressions typically had thousands of observations. Additionally, all of the continuous variables in each of the regressions had t -values that indicated statistical significance. The actual regression equations for Washington, D.C. are presented in Appendices 1 and 2. The regressions for the other markets are quite comparable and available from the author.

In all of the regressions, the coefficient for *AREA* is negative and significant at the 1.0% level. This is an expected outcome for several reasons. First, there is an economy of scale in all construction, and cost per square foot typically declines as the overall size of the project increases. This is due in part to economies of scale in production—larger projects typically have increased productivity due to the increased efficiency of repetitive work. Secondly, larger projects also often can exert market pressure in the purchase and assembly of materials on site. In the office equations, the average coefficient across markets was $-.0006$ (ranging

from $-.0004$ to $-.0008$). Thus for each additional 1000 square feet in building size (the variable's unit of measurement), costs per square foot drop by 0.06%. Thus a "large" suburban property of 100,000 square feet might be built for as much as 6% less per square foot than a "small" property of 4,000 square feet.

In the apartment regressions, the average coefficient for square feet was $-.001$, but the coefficient on *UNITS* was positive and of almost the same magnitude. Across markets, both ranged from $-.0007$ to $-.0015$ and are consistently significant at the 0.10% level. Hence, a larger number of smaller units in the same space cost more. With the semi-log specification it is a bit complicated to assess overall projects scale effects—holding unit size fixed. The cost per square foot for a 100-unit project with 50,000 square feet turns out to be about 5% more expensive than a 10-unit building with 5,000 square feet. At an average unit size of 500 square feet, scale increases costs. As unit size increases above 1,000 square feet, the impact reverses and there exist mild economies to project size. With luxury apartments, of typical 1,500 square foot size, a 100-unit building has 4% lower costs per square foot than a 10-unit project.

In all of the regressions, *STORIES* also has a positive and statistically significant coefficient. Again using the average coefficient across apartment markets of .03, 4-story buildings cost 6% more than 2-story. In the case of offices the impact is slightly less, with 4-stories costing 3% more on average.

In terms of framing and building technology, the regression results indicate that typically load bearing construction is the cheapest method, with wood frame construction costing almost the same. At the other extreme, concrete construction is typically the most expensive, with steel framing a close second. These latter two methods typically add between 10% and 20% to costs, but these coefficients exhibited much greater variation across markets than those for area, units, or stories. Quite likely, the exact definition of these structure types varies around the country.

Taking each of the yearly fixed effects, a time trend is calculated that is the same in percentage terms regardless of the other variables. This in turn is adjusted to real dollars, using the standard CPI series. Exhibit 3 shows the time trend for offices in the city of Dallas and Exhibit 4 displays the results for Chicago apartments. This is quite representative of the majority of cities. The indices for the illustrative city, Washington, D.C. are found in Appendices 3 and 4 and the results for the other markets are available from the author. In each case, the F.W. Dodge index is compared to two commercially available series: RS Means and ENR.

The first observation about Exhibits 3 and 4 is that the Means and ENR indices show remarkable uniformity across the six markets and two property types studied. In virtually every case, they rise about 20% in the 1970s and then fall about 20% between 1980 and 2003, ending near or slightly below where they began. It is difficult to believe that this pattern is so uniform across markets, but such

Exhibit 3 | Comparison of Construction Real Cost Indices for Dallas Offices

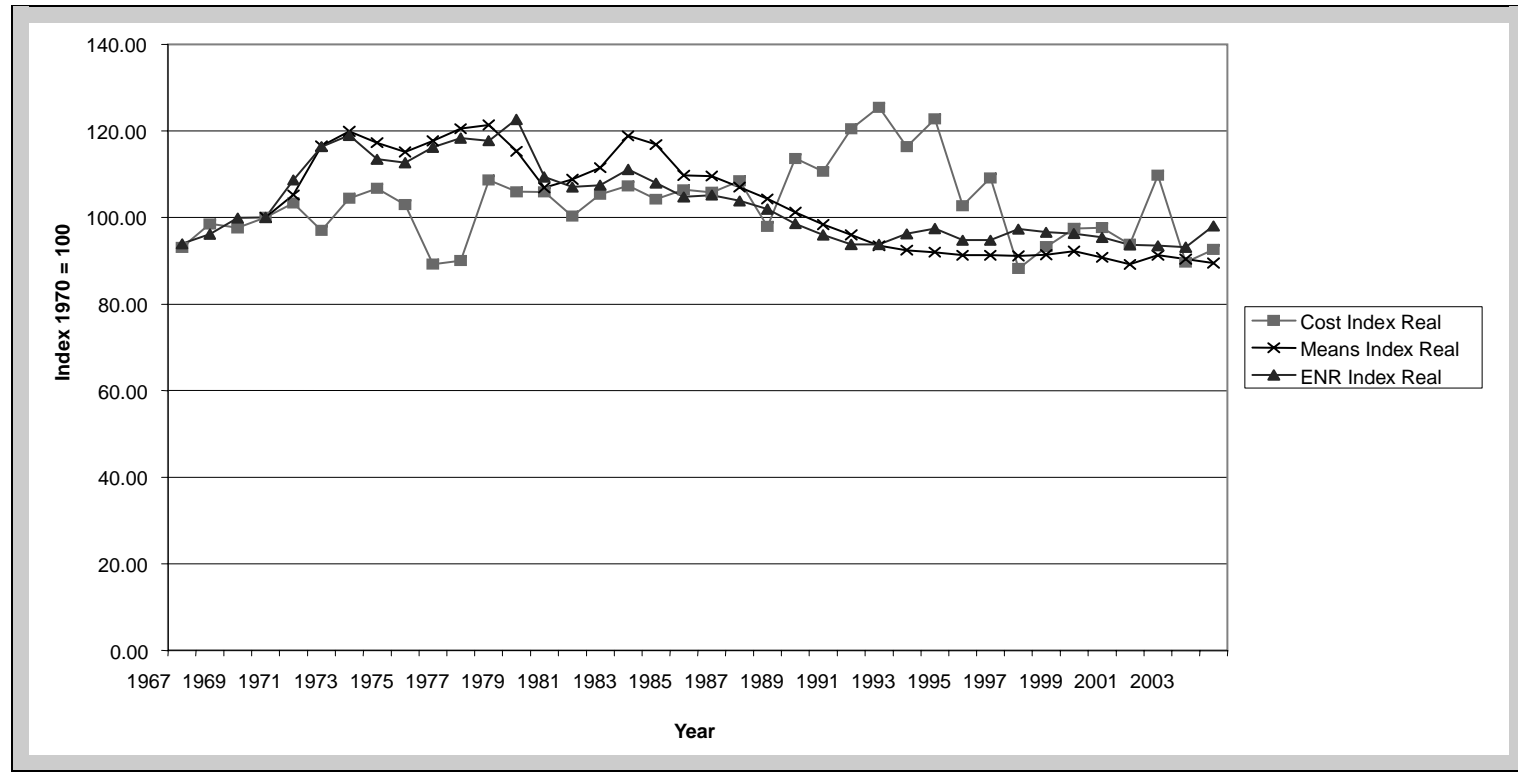
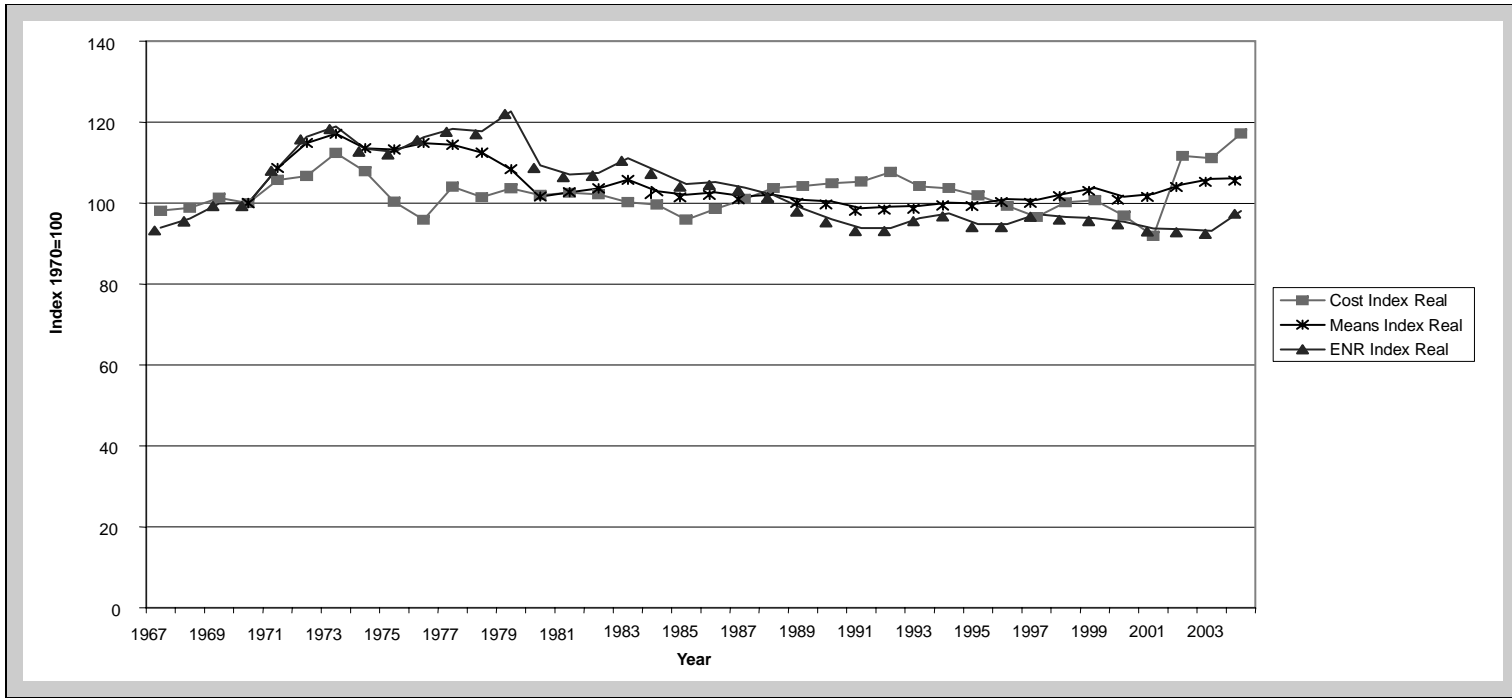


Exhibit 4 | Comparison of Construction Cost Indices for Chicago Apartments



uniformity may result from the combination of using fixed factor weights, national materials prices, and only local labor rates. While local labor rates vary widely in levels, if they have moved together across time, then the indices as constructed would indeed be very similar over time as well. The pattern is also almost identical across the two property types.

The time series patterns for the F.W. Dodge index show more variation across both market and property type. In general, office costs decline fairly steadily from between 10% and 30% from 1967 through 2004. For apartments, there is less decline, from 5% to 15% and one market, San Diego, actually has a 30% increase in real terms over this period. In the five markets that do show declines, there is also a tendency for costs to rise a bit in the early 1970s, as they do with the Means and ERN indices. However, the pattern is not as pronounced or uniform. The year to year variations in the F.W. Dodge indices are also much greater than those of the Means or ENR indices.

Unlike the Means and ERN data, in several markets the F.W. Dodge indices also show a recent climb over the 2001–2004 period. This is true in almost half of the market-property types studied. This occurs for apartments in San Diego, Phoenix, Denver, and Chicago and for offices in San Diego as well. By contrast, the other indices continue to decline smoothly over the last few years.

Elasticity of Construction Costs to Building Activity

A central question in this paper is whether the yearly or cyclic movements in the F.W. Dodge indices, which are much more pronounced than in either the Means or ENR indices, is in any way related empirically to the volume of building activity. Methodologically, the stationarity of the series is examined to see if regression analysis is appropriate or a co-integration approach needs to be applied. Having determined the correct procedure, the relationship between the two series is examined.

Exhibit 5 depicts two series for Denver apartments. The building activity series used is new permits for multi-family development. In the case of offices (Exhibit 6), completions of new office space are used (as tallied by real estate brokers in each market). Denver is quite typical of the apartment market in that the cost index shows considerable small movement between years, while building activity displays three large “swings” over the period studied. Most apartments were built in waves during the early 1970s, mid 1980s, and then most recently. In between these periods, construction was extremely low.

Using a simple AR1 model, both series are found to have a high degree of autocorrelation. The coefficient on lagged costs ranges between .45 and .69 across the six markets. The coefficient on lagged starts is a bit stronger ranging from .52 to .79. In every one of these cases, if an equation is estimated between *changes* in costs or building activity and lagged levels of the variable, the lagged level coefficient (1 minus the AR1 coefficient) is statistically significant at the 5% level.

Exhibit 5 | Denver Apartment Real Construction Cost Index vs. New Apartment Supply

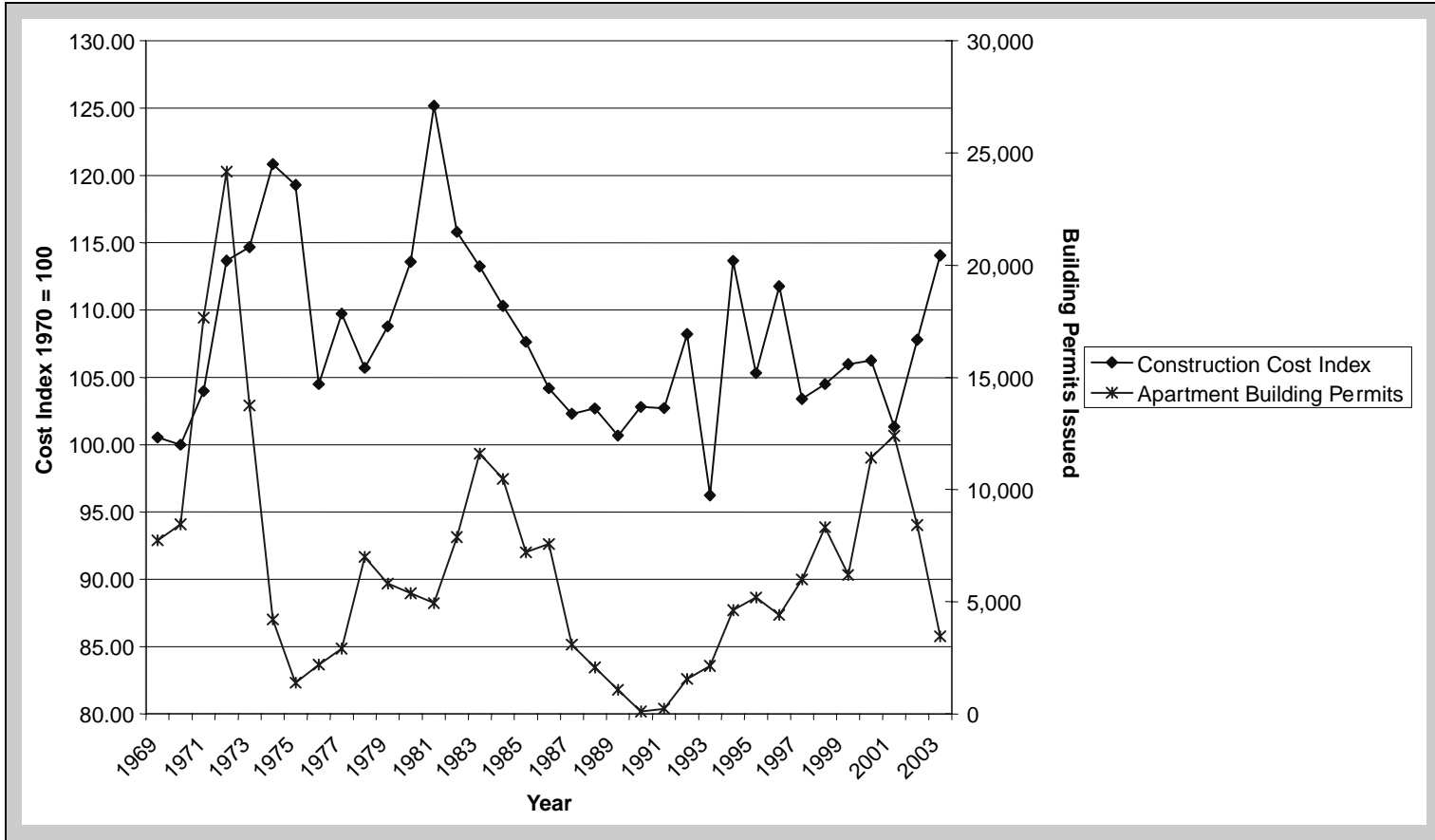
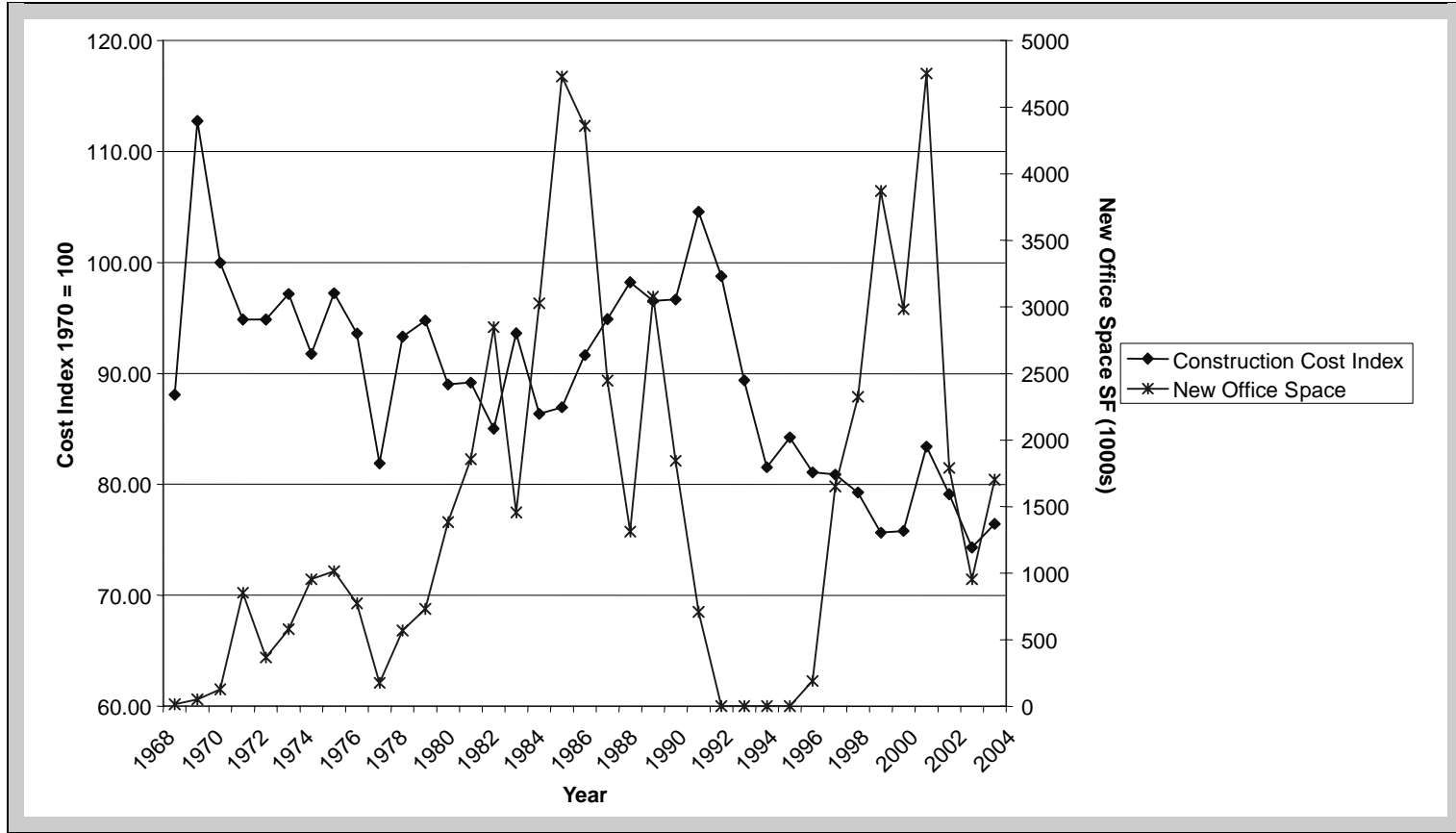


Exhibit 6 | Phoenix Office Real Construction Cost Index vs. New Office Supply



A model in either levels or differences clearly exhibits mean reversion for both series. Using a simple Dickey-Fuller test, if the cost series are truly random walks, then coefficients this far from unity would happen at most 10% of the time. The findings indicate that this level too high; thus, the Dickey-Fuller null is rejected, even though this test is thought to have quite low power with only 37 observations. Similarly, this null is rejected in the case of construction. Both series display considerable mean reversion at annual frequency. In all of the apartment markets examined, this same conclusion holds. The graph for the sample market (Washington) is shown in Appendix 5. Upon casual inspection of this graph, there seems to be little evidence of an obvious relationship between the cost series and apartment building activity. The graphs for all apartment markets are available from the authors upon request.

With offices, the story is much the same. Exhibit 6 shows Phoenix office space completions over this time frame, again in comparison with the cost index. With offices there is even more clustering of development. The mid 1980s saw enormous completions of space, while the boom of the early 1970 was smaller in most markets. Recently, there was another building boom, although in some markets it has been more modest in comparison to that of the 1980s. The statistical results are very similar to that of apartments. In all six markets, there is statistically significant mean reversion and the random walk model can be accepted for both completions and the construction cost index only at low confidence levels. The graph for the sample Washington, D.C. office market is shown in Appendix 6, and again there appears to be no obvious connection between the two series.

With similar results on stationarity for the two series, traditional regression analysis was deemed appropriate. However, an important question remains as to the relationship that should be expected between construction costs and building activity. If this relationship is thought of as embodying a supply curve, it should be positive—unless the industry as a whole (at least at the MSA level) is believed to display increasing returns. In this case, the relationship could conceivably be negative.

Somerville (1999) has argued that the relationship between these two series could also represent a derived demand curve from new development. Development is a natural real option that is exercised when asset prices minus construction costs exceed some “hurdle” value. As costs rise, less development is undertaken (*ceteris paribus*) and so the level of building activity would decrease. At the micro-economic level, Somerville provides some evidence of this, but at the aggregate level others argue that the relationship between construction costs and building activity is purely a supply curve (Blackley, 1999). In principle, some instrument could be employed for construction costs (such as international materials prices), which would allow the identification of any demand relationship. Similarly, using an instrument for demand will allow identification of the supply relationship. Given that the interest here is in supply, a simple correlation analysis between the two series will be employed followed by an Instrumental Variables (IV) identification to pick out the impact of purely demand-induced building activity

on costs. The annual rate of economic growth in each market, along with national interest rates and economy-wide inflation will be used as instruments.

For apartments, it seems plausible that bid costs would be impacted (if at all) by the volume of activity at the time the bid is made—that being approximately when the permit is issued (at least the same year). For office space, however, only the date of building completion is known, and it would seem reasonable to allow for a year of two lag. Hence, if office building activity did impact costs, it would be between costs at time t and activity (as measured) at time $t + 1$ or $t + 2$. In addition to testing for a simply bivariate relationship between costs and building activity, tests also examined whether there were some more gradual “adjustment” process at work in which activity levels more slowly moved costs. This was done by regressing costs against both building activity and lagged costs.

Exhibit 7 gives the results for all six apartment markets of the contemporaneous correlation between apartment permits and construction costs (rows 1 and 2), and then including lagged costs as well (rows 3–5). In only one market, San Diego, is there a significant relationship between cost and activity and it is negative. This likely reflects largely secular and not cyclic phenomena. During the last 35 years, construction costs in San Diego have clearly trended upward (unlike the other markets) while apartment building cycles have become smaller. Their decrease has induced a downward trend in the number of permits. Including lagged costs in the equation boost R^2 values considerably (given the mean reversion of the series this is not surprising) but never makes the level of building activity statistically significant.

The final rows two rows of Exhibit 7 present the IV results. In the six markets studied, the first-stage R^2 values range from .28 to .59, when economic growth,

Exhibit 7 | Apartment Cost/Starts Results

| | Chicago | Dallas | Denver | Phoenix | San Diego | Washington, D.C. |
|---|---------|--------|--------|---------|-----------|------------------|
| OLS | | | | | | |
| R^2 : cost | 0.003 | 0.006 | 0.006 | 0.036 | 0.190 | 0.003 |
| T: starts | 0.32 | -0.14 | 0.46 | 1.15 | -2.86 | 0.35 |
| R^2 : cost | 0.310 | 0.430 | 0.250 | 0.210 | 0.570 | 0.360 |
| T: starts | 1.56 | 0.03 | 0.71 | 0.53 | -1.21 | 0.71 |
| T: cost-1 | 3.93 | 5.12 | 3.22 | 2.72 | 5.51 | 4.37 |
| IV ^a | | | | | | |
| R^2 : cost | 0.048 | 0.001 | 0.012 | 0.036 | 0.210 | 0.012 |
| T: starts | 1.28 | 0.04 | 0.62 | 0.85 | -2.96 | 0.56 |
| Notes: | | | | | | |
| ^a Instruments are MSA employment growth, 10 year T-bill rate, CPI inflation. | | | | | | |

inflation, and interest rates are used as instruments for building activity. In no case are the presented second-stage results either statistically significant or much different from the OLS equations.

Exhibit 8 provides a similar analysis for the six office markets. Only in Phoenix is there any statistically significant relationship between construction costs and building activity. This holds regardless of whether a contemporaneous relationship is examined or one in which costs are related to completions one or two years hence. Similar to apartments, adding in lagged costs for any city boosts the fit of the model (again to be expected), but does not reveal any kind of statistical significance. In the case of Phoenix, the significant relationship is negative and again this seems to reflect secular trends. Over the last 35 years, office construction costs have trended down more strongly in this market than others, while office building cycles have increased as the metro area rapidly grew this sector of its economy. The increasing amplitude of the office cycles produces an upward trend in building activity.

The final rows of Exhibit 8 again test for endogeneity of building activity. Using the same instruments as in Exhibit 7, the first-stage equations have fits that range from .21 to .63 across the six markets. In the second stage, there is again little change from the OLS results and only Phoenix is significant. The IV results are presented only when using a two period forward lag on costs since the F.W. Dodge company felt that two years was the most reasonable construction lag for office developments.

Exhibit 8 | Office Cost/Completions Results

| | Chicago | Dallas | Denver | Phoenix | San Diego | Washington, D.C. |
|-----------------|---------|--------|--------|---------|-----------|------------------|
| R^2 : cost | 0.013 | 0.001 | 0.000 | 0.098 | 0.015 | 0.007 |
| T: compl | 0.71 | 0.05 | -0.11 | -1.98 | 0.71 | -0.49 |
| R^2 : cost | 0.007 | 0.010 | 0.003 | 0.170 | 0.018 | 0.015 |
| T: compl+1 | 0.51 | -0.64 | 0.33 | -2.66 | 0.79 | -0.74 |
| R^2 : cost | 0.013 | 0.021 | 0.005 | 0.210 | 0.047 | 0.014 |
| T: compl+2 | 0.21 | -0.83 | 0.41 | -2.84 | 1.28 | -0.69 |
| R^2 : cost | 0.48 | 0.28 | 0.27 | 0.41 | 0.48 | 0.37 |
| T: compl+2 | 0.68 | -0.77 | 0.16 | -1.22 | 0.83 | -0.56 |
| T: cost-1 | 5.53 | 3.42 | 3.29 | 3.32 | 5.18 | 0.23 |
| IV ^a | | | | | | |
| R^2 : cost | 0.003 | 0.045 | 0.014 | 0.21 | 0.063 | 0.017 |
| T: compl+2 | 0.11 | -1.23 | 0.67 | -2.74 | 1.43 | -0.74 |

Notes:
^aInstruments are MSA employment growth, 10 year T-bill rate, CPI inflation.

Conclusion

The objective of this paper has been quite simple: to estimate a building cost index based on actual construction projects in several markets and for multiple property types and then to study their cyclic and secular behavior over the last 35 years. The conclusions are likewise simple. First, the F.W. Dodge data produces cost indices that are generally smooth over time, if a bit noisy year-to-year. There have been no large “swings” or “movements” since the late 1960s. Secondly, the indices generally show a slight decline over time in constant dollars. This certainly indicates that the construction sector has seen some productivity growth over the last several decades. It is also consistent with real estate market information showing that in many commercial markets, rents and asset prices—adjusted for inflation—also have not risen over the last few decades. Real estate markets are supposed to mean revert around long run replacement costs. Thus if the land component of total replacement costs also has not increased much beyond inflation, as might be the case if more and more development is occurring in the suburbs, then there is a complete picture of real estate markets as having long run asset prices that are effectively stationary in real terms.

The second major conclusion is that there appears to no impact of the quite pronounced real estate development “cycle” on construction costs. Apartment and office development in the six markets studied has had a very noticeable cycle over the 35 years between 1968 and 2003. At the most basic level, there is just no obvious or statistical reduced form relationship between the two series. This could of course represent offsetting supply and demand impacts. Greater development puts pressure on construction costs, but greater construction costs also reduce the profitability of new development—given market asset prices. To study this issue in more detail, more national and regional economic variables need to be developed. In effect the impact of “demand predicted” development on costs is examined, which also turns out to be nil.

Thus the overall conclusion is that the construction industry seems to be supplied with a very high elasticity to local development demand. This is consistent with most of the “Urban Economics” literature in which capital is regarded as a perfectly traded good between markets. Only land is scarce and it receives both short run and long run Ricardian scarcity rent. This research clearly supports this view.

Appendix 1

Chicago Apartments

| Ln(cost/sf) | Coeff. | Std. Err. | t | P > t | 95% Conf. Interval | |
|-------------|---------|-----------|--------|-------|--------------------|---------|
| Area | -0.0009 | 0.00008 | -11.06 | 0.000 | -0.0011 | -0.0008 |
| Units | 0.0010 | 0.00009 | 10.24 | 0.000 | 0.0008 | 0.0011 |
| Stories | 0.0121 | 0.00091 | 13.23 | 0.000 | 0.0103 | 0.0139 |
| Steel | 0.1043 | 0.01269 | 8.22 | 0.000 | 0.0794 | 0.1292 |
| Wood | 0.0351 | 0.00709 | 4.96 | 0.000 | 0.0212 | 0.0490 |
| Concrete | 0.1049 | 0.01708 | 6.14 | 0.000 | 0.0714 | 0.1384 |
| Other/Unk | -0.0032 | 0.01033 | -0.31 | 0.757 | -0.0234 | 0.0170 |
| 1967 | -1.9112 | 0.03853 | -49.60 | 0.000 | -1.9867 | -1.8357 |
| 1968 | -1.8634 | 0.03911 | -47.64 | 0.000 | -1.9401 | -1.7867 |
| 1969 | -1.7851 | 0.03875 | -46.07 | 0.000 | -1.8611 | -1.7092 |
| 1970 | -1.7425 | 0.03930 | -44.34 | 0.000 | -1.8195 | -1.6654 |
| 1971 | -1.6436 | 0.03790 | -43.37 | 0.000 | -1.7179 | -1.5693 |
| 1972 | -1.6028 | 0.03726 | -43.01 | 0.000 | -1.6758 | -1.5298 |
| 1973 | -1.4906 | 0.03758 | -39.67 | 0.000 | -1.5643 | -1.4169 |
| 1974 | -1.4274 | 0.03957 | -36.07 | 0.000 | -1.5050 | -1.3498 |
| 1975 | -1.4122 | 0.04049 | -34.88 | 0.000 | -1.4916 | -1.3329 |
| 1976 | -1.4015 | 0.03875 | -36.17 | 0.000 | -1.4775 | -1.3256 |
| 1977 | -1.2567 | 0.03782 | -33.23 | 0.000 | -1.3308 | -1.1825 |
| 1978 | -1.2090 | 0.03845 | -31.45 | 0.000 | -1.2843 | -1.1336 |
| 1979 | -1.0801 | 0.03827 | -28.23 | 0.000 | -1.1551 | -1.0051 |
| 1980 | -0.9695 | 0.03999 | -24.25 | 0.000 | -1.0479 | -0.8912 |
| 1981 | -0.8662 | 0.04157 | -20.84 | 0.000 | -0.9476 | -0.7847 |
| 1982 | -0.8094 | 0.04278 | -18.92 | 0.000 | -0.8933 | -0.7256 |
| 1983 | -0.7974 | 0.04060 | -19.64 | 0.000 | -0.8770 | -0.7178 |
| 1984 | -0.7608 | 0.03956 | -19.23 | 0.000 | -0.8384 | -0.6833 |
| 1985 | -0.7639 | 0.03895 | -19.61 | 0.000 | -0.8402 | -0.6875 |
| 1986 | -0.7184 | 0.03838 | -18.72 | 0.000 | -0.7937 | -0.6432 |
| 1987 | -0.6578 | 0.03822 | -17.21 | 0.000 | -0.7327 | -0.5829 |
| 1988 | -0.5911 | 0.03825 | -15.45 | 0.000 | -0.6660 | -0.5161 |
| 1989 | -0.5161 | 0.03833 | -14.07 | 0.000 | -0.6145 | -0.4643 |
| 1990 | -0.4800 | 0.03897 | -12.32 | 0.000 | -0.5564 | -0.4036 |
| 1991 | -0.4348 | 0.03988 | -10.90 | 0.000 | -0.5130 | -0.3567 |
| 1992 | -0.3834 | 0.03954 | -9.69 | 0.000 | -0.4609 | -0.3059 |

Appendix 1 (continued)

Chicago Apartments

| Ln(cost/sf) | Coeff. | Std. Err. | <i>t</i> | <i>P</i> > <i>t</i> | 95% Conf. Interval | |
|-------------|---------|-----------|----------|---------------------|--------------------|---------|
| 1993 | -0.3866 | 0.03950 | -9.79 | 0.000 | -0.4640 | -0.3091 |
| 1994 | -0.3664 | 0.04118 | -8.90 | 0.000 | -0.4471 | -0.2857 |
| 1995 | -0.3557 | 0.04492 | -7.92 | 0.000 | -0.4437 | -0.2676 |
| 1996 | -0.3525 | 0.04039 | -8.73 | 0.000 | -0.4316 | -0.2733 |
| 1997 | -0.3571 | 0.03798 | -9.40 | 0.000 | -0.4315 | -0.2826 |
| 1998 | -0.3055 | 0.03934 | -7.76 | 0.000 | -0.3826 | -0.2284 |
| 1999 | -0.2782 | 0.04044 | -6.88 | 0.000 | -0.3575 | -0.1989 |
| 2000 | -0.2840 | 0.04413 | -6.44 | 0.000 | -0.3705 | -0.1975 |
| 2001 | -0.3085 | 0.04064 | -7.59 | 0.000 | -0.3882 | -0.2289 |
| 2002 | -0.0980 | 0.04310 | -2.27 | 0.023 | -0.1825 | -0.0136 |
| 2003 | -0.0804 | 0.04169 | -1.93 | 0.054 | -0.1622 | 0.0013 |
| _cons | 4.3215 | 0.03558 | 121.46 | 0.000 | 4.2517 | 4.3912 |

Notes: The number of observations is 12,259. Other data are: $F(44, 12,214) = 887.01$; Prob > $F = 0.0000$; $R^2 = 0.7616$; and Root MSE = 0.3071.

| Source | SS | df | MS |
|----------|------------|--------|---------|
| Model | 3,679.5705 | 44 | 83.6266 |
| Residual | 1,151.5221 | 12,214 | 0.0943 |
| Total | 4,831.0926 | 12,258 | 0.3941 |

Appendix 2

Dallas Apartments

| Ln(cost/sf) | Coeff. | Std. Err. | <i>t</i> | <i>P</i> > <i>t</i> | 95% Conf. Interval | |
|-------------|---------|-----------|----------|---------------------|--------------------|---------|
| Area | -0.0010 | 0.00012 | -7.80 | 0.000 | -0.0012 | -0.0007 |
| Units | 0.0004 | 0.00011 | 3.64 | 0.000 | 0.0002 | 0.0006 |
| Stories | 0.0300 | 0.00409 | 7.34 | 0.000 | 0.0220 | 0.0380 |
| Steel | 0.1372 | 0.03733 | 3.67 | 0.000 | 0.0640 | 0.2103 |
| Wood | 0.0504 | 0.01430 | 3.52 | 0.000 | 0.0224 | 0.0784 |
| Concrete | 0.2238 | 0.05311 | 4.21 | 0.000 | 0.1198 | 0.3280 |

Appendix 2 (continued)

Dallas Apartments

| Ln(cost/sf) | Coeff. | Std. Err. | t | P > t | 95% Conf. Interval | |
|-------------|---------|-----------|--------|-------|--------------------|---------|
| Other/Unk | 0.0465 | 0.02095 | 2.22 | 0.027 | 0.0054 | 0.0875 |
| 1967 | -1.8746 | 0.08147 | -23.01 | 0.000 | -2.0343 | -1.7150 |
| 1968 | -1.8044 | 0.07970 | -22.64 | 0.000 | -1.9607 | -1.6480 |
| 1969 | -1.6626 | 0.07228 | -23.00 | 0.000 | -1.8044 | -1.5209 |
| 1970 | -1.6387 | 0.07201 | -22.76 | 0.000 | -1.7800 | -1.4975 |
| 1971 | -1.6165 | 0.07132 | -22.67 | 0.000 | -1.7564 | -1.4767 |
| 1972 | -1.4809 | 0.07191 | -20.59 | 0.000 | -1.6219 | -1.3399 |
| 1973 | -1.3820 | 0.07401 | -18.67 | 0.000 | -1.5271 | -1.2369 |
| 1974 | -1.3240 | 0.07560 | -17.51 | 0.000 | 1.4722 | -1.1757 |
| 1975 | -1.3968 | 0.08057 | -17.34 | 0.000 | -1.5548 | -1.2389 |
| 1976 | -1.4040 | 0.08092 | -17.35 | 0.000 | -1.5627 | -1.2454 |
| 1977 | -1.3359 | 0.07354 | -18.17 | 0.000 | -1.4801 | -1.1918 |
| 1978 | -1.2059 | 0.07703 | -15.66 | 0.000 | -1.3569 | -1.0549 |
| 1979 | -1.0489 | 0.07475 | -14.03 | 0.000 | -1.1954 | -0.9023 |
| 1980 | -0.8330 | 0.07401 | -11.25 | 0.000 | -0.9781 | -0.6879 |
| 1981 | -0.7093 | 0.07248 | -9.79 | 0.000 | -0.8514 | -0.5672 |
| 1982 | -0.6046 | 0.07140 | -8.47 | 0.000 | -0.7446 | -0.4646 |
| 1983 | -0.6043 | 0.07002 | -8.63 | 0.000 | -0.7415 | -0.4670 |
| 1984 | -0.5788 | 0.07040 | -8.22 | 0.000 | -0.7168 | -0.4408 |
| 1985 | -0.5758 | 0.07073 | -8.14 | 0.000 | -0.7145 | -0.4372 |
| 1986 | -0.5913 | 0.07252 | -8.15 | 0.000 | -0.7335 | -0.4491 |
| 1987 | -0.4358 | 0.08221 | -5.30 | 0.000 | -0.5969 | -0.2746 |
| 1988 | -0.4018 | 0.09318 | -4.31 | 0.000 | -0.5845 | -0.2192 |
| 1989 | -0.3216 | 0.10664 | -3.02 | 0.003 | -0.5307 | -0.1125 |
| 1990 | -0.2987 | 0.08668 | -3.45 | 0.001 | -0.4686 | -0.1288 |
| 1991 | -0.2574 | 0.09186 | -2.80 | 0.005 | -0.4375 | -0.0773 |
| 1992 | -0.4130 | 0.10154 | -4.07 | 0.000 | -0.6121 | -0.2139 |
| 1993 | -0.3153 | 0.10148 | -3.11 | 0.002 | -0.5142 | -0.1163 |
| 1994 | -0.2737 | 0.07939 | -3.45 | 0.001 | -0.4294 | -0.1181 |
| 1995 | -0.2451 | 0.08125 | -3.02 | 0.003 | -0.0404 | -0.0858 |
| 1996 | -0.2336 | 0.07825 | -2.99 | 0.003 | -0.3870 | -0.0802 |
| 1997 | -0.2429 | 0.07587 | -3.20 | 0.001 | -0.3917 | -0.0942 |
| 1998 | -0.0967 | 0.07303 | -1.32 | 0.186 | -0.2399 | 0.0465 |

Appendix 2 (continued)

Dallas Apartments

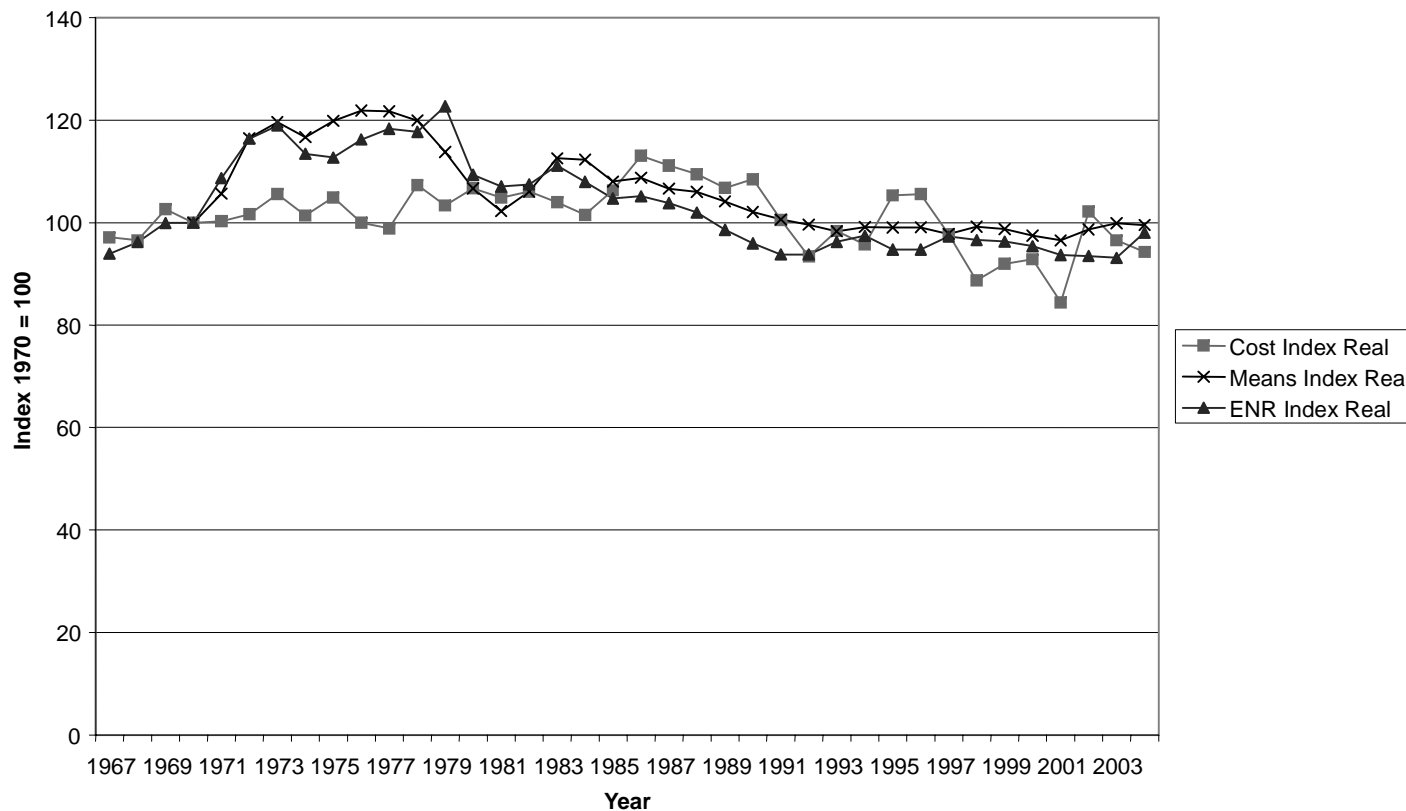
| Ln(cost/sf) | Coeff. | Std. Err. | <i>t</i> | <i>P</i> > <i>t</i> | 95% Conf. Interval | |
|-------------|---------|-----------|----------|---------------------|--------------------|--------|
| 1999 | -0.1117 | 0.07599 | -1.47 | 0.142 | -0.2607 | 0.0373 |
| 2000 | -0.0218 | 0.07634 | -0.29 | 0.775 | -0.1715 | 0.1279 |
| 2001 | -0.0025 | 0.07881 | -0.03 | 0.975 | -0.1570 | 0.1520 |
| 2002 | -0.0296 | 0.07737 | -0.38 | 0.703 | -0.1813 | 0.1221 |
| 2003 | 0.0080 | 0.07832 | 0.10 | 0.919 | -0.1456 | 0.1615 |
| _cons | 3.9562 | 0.07038 | 56.21 | 0.000 | 3.8182 | 4.0942 |

Notes: The number of observations is 3,777. Other data are: $F(44, 3,732) = 332.61$; Prob > F = 0.0000; $R^2 = 0.7944$; and Root MSE = 0.2807.

| Source | SS | df | MS |
|----------|------------|-------|---------|
| Model | 1,153.2285 | 44 | 26.2097 |
| Residual | 294.0864 | 3,732 | 0.0788 |
| Total | 1,447.3149 | 3,776 | 0.3833 |

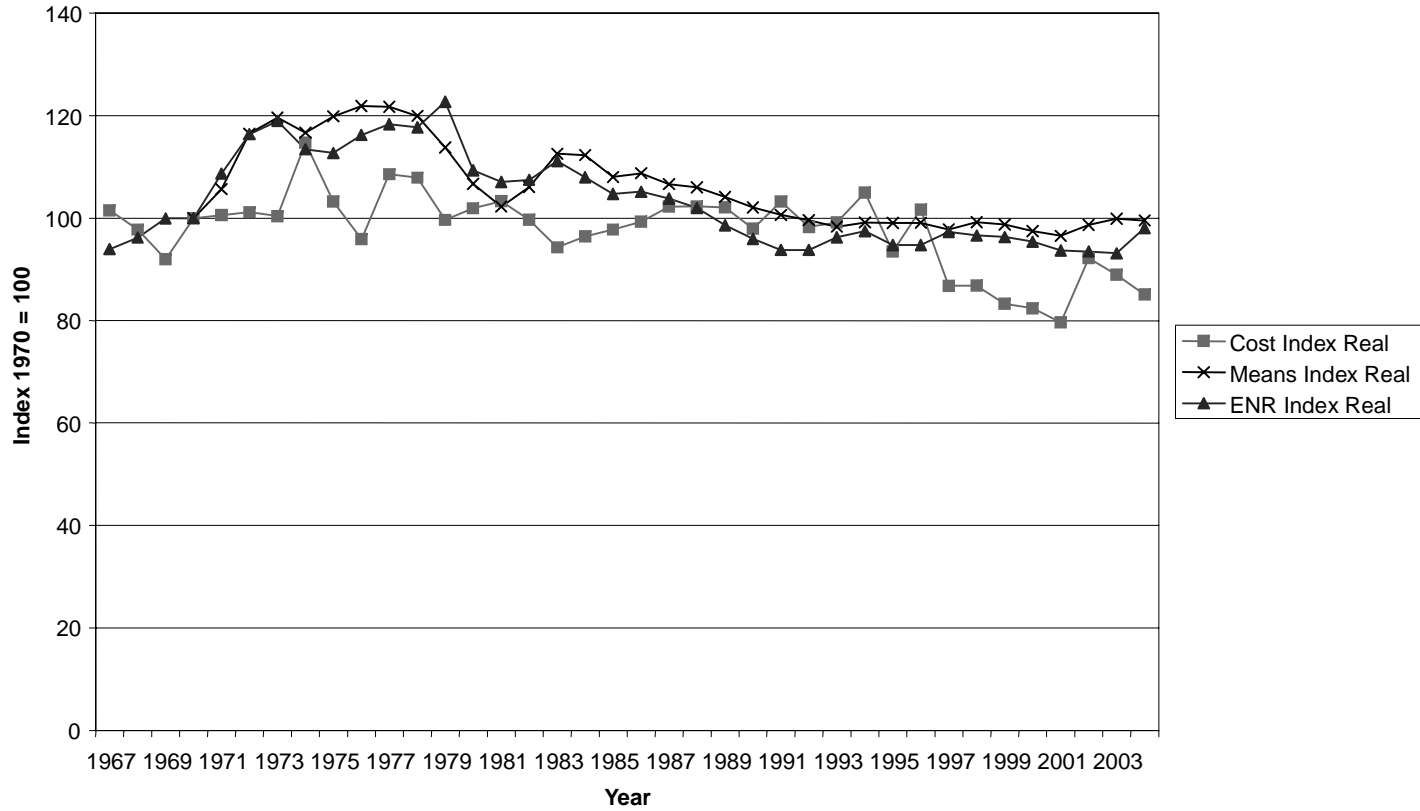
Appendix 3

Comparison of Construction Cost Indices for Washington, D.C. Apartments



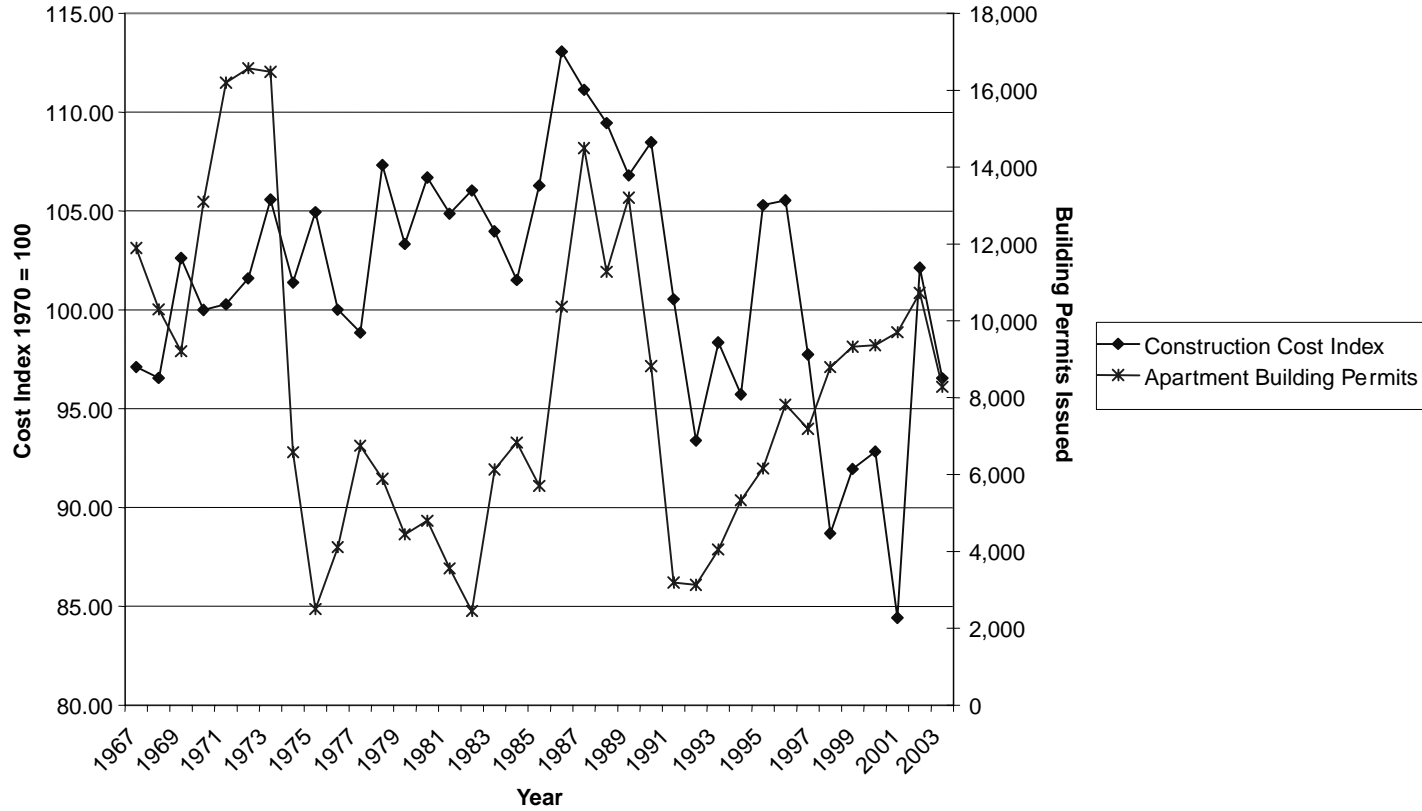
Appendix 4

Comparison of Construction Real Cost Indices for Washington, D.C. Offices



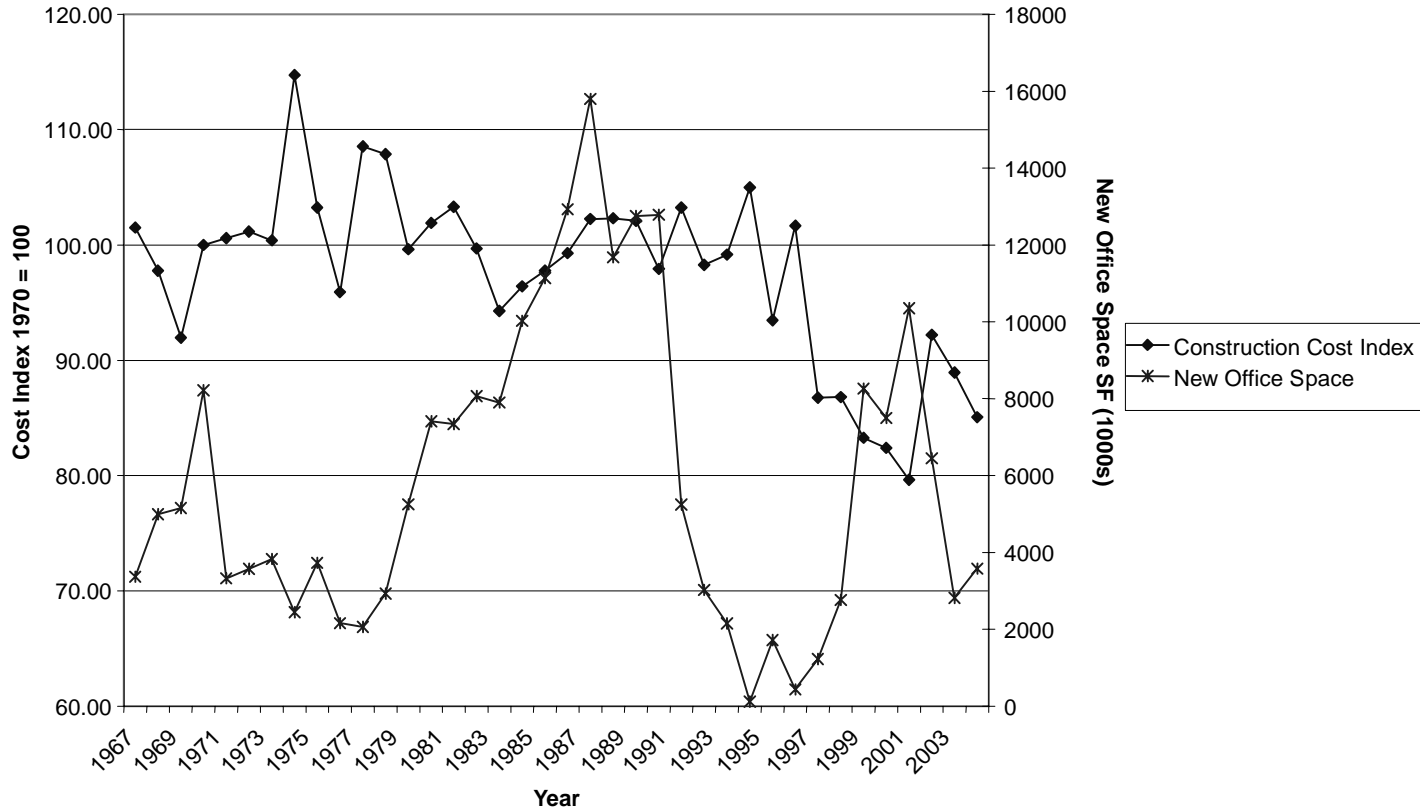
Appendix 5

Washington, D.C. Apartment Real Construction Cost Index vs. New Apartment Supply



Appendix 6

Washington, D.C. Office Real Construction Cost Index vs. New Office Supply



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