Journal of Cost Analysis and Parametrics, 9:201–207, 2016

ISSN: 1941-658X print / 2160-4746 online
DOI: 10.1080/1941658X.2016.1266974

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Dynamics of New Building Construction Costs: Implications for Forecasting Escalation Allowances

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Construction projects often require multiple years to complete and the costs of supplies, materials, and labor may increase substantially during a project's time span. As a result, construction contracts often include an escalation clause to account for cost increases. This article examines the time-series properties of new building construction costs using several producer price indexes. Using a battery of unit root tests, we find substantial evidence that construction cost indexes are generally nonstationary. This finding has implications for the proper specification and use of these series in contract escalation clauses and their respective use in forecasting construction cost increases.

Introduction

The construction industry has been plagued with time and cost overruns (Flyvbjerg, Holm, Mette, & Buhl, 2002). Shane, Molenaar, Anderson, and Schexnayder (2009) further indicate that project costs exceed cost estimates in many cases. This scenario is troubling from a project manager's perspective in attempting to forecast future construction costs for projects that can last months to many years in the future. As such, it is important to understand the cost-driving factors on such projects (Cheng, 2014). However, if costs are predictably high, then adjustments can be made to account for such contingencies or to mitigate the risk of cost overruns. For example, Love, Wang, Sing, and Tiong (2013) examined several construction projects and found that they averaged a cost overrun of approximately 12%. If these projects average a cost increase of 12%, then that increase may be factored into the original contract. Doing so becomes even more important considering that projects, especially large ones, are financing capital purchases throughout the construction process. However, it is important to understand how these costs behave over time. That is, are costs stationary and revert back to some long-run mean. If so, then using historical costs data can possibly lead to better cost forecasts. If costs are nonstationary, then the use of historical data may add no useful information for developing cost forecasts. This situation motivates us to examine whether or not, and to what degree, construction costs are predictable.

If construction cost increases are indeed predictable, then they may be factored into the project contract via an escalation clause. An escalation clause is simply an anticipated or expected increase in the cost of constructing a building over some defined period. Cost increases typically arise from market forces that result in higher prices for labor or materials, especially over the longer-term nature of construction projects. Previous research

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has examined the predictability or forecastability of different construction industry metrics (Ewing, Liang, & Thompson, 2006; Fan, Ng, & Wong, 2010; Gideon & Wasek, 2015; Hua & Pin, 2000; Jiang & Liu, 2011; Ng, Cheung, Skitmore, & Wong, 2004). While construction contracts vary by the degree of risk sharing among parties, time span of the project, etc., one cost measure on which contractors and suppliers base their escalation clauses is the producer price index (PPI) published by the Bureau of Labor Statistics (BLS). In fact, the Associated General Contractors of America (AGC) compiles a wealth of information about the construction industry, including current trends in construction prices using data from the BLS. However, the accurate use of these indexes in escalation clauses depends on their underlying time series properties. Understanding the stochastic behavior of these indexes over time is critical if they are to be used appropriately in escalation clauses.

For example, if new building construction PPI is a non-stationary process (i.e., contains a unit root), then unexpected changes in the PPI will result in a permanent impact on the price series. On the other hand, if the price index is stationary, then unexpected changes (i.e., shock) will be temporary, or transitory in nature, and the price series will revert to some long-run mean. Accordingly, when using these indexes for escalation clauses, it is important to determine whether the relevant index is stationary or non-stationary. Furthermore, understanding whether the respective series are stationary or non-stationary can aid in modeling or forecasting new building construction costs. If the series is stationary, then past behavior (or history) can be used to develop forecasts. This information will result in better cost estimates during the project time span. As such, we use a battery of unit root tests to examine the time series properties of new building construction PPIs and discuss the implications of using these metrics in escalation clauses. Furthermore, since the BLS groups new building construction PPIs into several categories to account for various types of projects, we examine the PPI stationarity/unit root properties for four distinct types of construction projects: industrial, warehouse, school, and office.

Time Series Properties of New Building Construction Costs

In order to determine the stationarity properties of the BLS PPI new building construction series, we employ the unit root tests developed by Dickey-Fuller (1979), Elliott, Rothenberg, and Stock (1996), Phillips and Perron (1988), and Kwiatkowski, Phillips, Schmidt, and Shin (1992). The augmented Dickey-Fuller (ADF) test is based on the ordinary least squares regression of Equation (1):

$$\Delta y_t = \rho_0 + (\rho_1 - 1)y_{t-1} + \rho_2 t + \sum_{k=1}^{m} \delta_k \Delta y_{t-k} + e_t, \tag{1}$$

where y_t is the series under investigation (e.g., natural logarithm of new building construction series), Δ is the first-difference operator, t is a linear time trend, e_t is a covariance stationary random error, and m is determined by Schwarz information criteria to ensure serially uncorrelated residuals. The null hypothesis is that y_t is a nonstationary time series and is rejected if $(\rho_1 - 1) < 0$ and statistically significant. The finite sample critical values for the ADF test developed by MacKinnon (1996) are used to assess statistical significance. The Dickey-Fuller generalized least squares (DF-GLS) unit root test estimates the standard DF equation (1), but substitutes y_t^j with the GLS detrended series, $\tilde{y}_t^j$.[1] Since the asymptotic distribution of the DF-GLS t-ratio differs from the DF distribution, the critical values provided by Elliott et al. (1996) are used.

Likewise, the Phillips and Perron (1988) unit root test allows for weak dependence, heterogeneity in the error term, and is robust to a wide range of serial correlation and time-dependent heteroskedasticity. The Phillips–Perron (PP) test is based on the following regression:

$$y_t = \eta_0 + \eta_1(t - T/2) + \lambda y_{t-1} + v_t, \tag{2}$$

where (t – $T/2$) is the time trend with T representing the sample size and v_t is the error term. The null hypothesis of a unit root, H_0: $\lambda = 1$, is tested against the alternative hypothesis that y_t is stationary around a deterministic trend (H_a: $\lambda < 1$). As in the ADF test, MacKinnon (1996) noted that critical values also are used to determine statistical significance for the PP test.

Alternatively, the Kwiatkowski et al. (1992) unit root test differs from the ADF and PP unit root tests in that the new building construction series is assumed to be (trend-) stationary under the null hypothesis. The Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) unit root test statistic is obtained from the residuals by regressing y_t on a constant and a trend, and is defined as the Lagrange multiplier (LM) statistic:

$$KPSS = \left(T^{-2} \sum_{t=1}^{T} \hat{S}_t^2 \right) / \hat{\lambda}^2, \tag{3}$$

where $\hat{S}_t$ is the sum of the residuals on the regression, $\hat{\lambda}^2$ is the consistent estimate of the long-run variance, and T is the sample size. Critical values from the asymptotic distributions for the KPSS test statistic are provided in Kwiatkowski et al. (1992). The null hypothesis of stationarity is rejected if the KPSS test statistic exceeds the respective critical value.

Actually, five new building construction PPIs are published by the BLS: new industrial building construction, new warehouse building construction, new school building construction, new office building construction, and new health-care building construction. However, the new health-care building construction is much newer than the other indexes and does not have a sufficient number of observations to examine the time series properties using these unit root tests. Figure 1 provides plots of the four (seasonally adjusted) construction cost series. The sample periods for each series differ depending on data availability. While the series generally move together over time and exhibit similar patterns, the extent and degree of increase/decline in any particular period often differ. Thus, it is not entirely apparent whether or not each of the PPI series will exhibit the same time series behavior. The results of the unit root tests for the four new building construction cost series are reported in Table 1.

Results and Implications

Generally speaking, the unit root test results indicate that each of the new building construction series is difference-stationary. That is, each series in level form is non-stationary and requires first-differencing to make the series stationary. These results are robust across the different unit root tests. For example, three of the four unit root tests support the conclusion that the new industrial building construction and new office building construction series are difference-stationary, and all four unit root tests support first differencing for the new warehouse building construction and the new school building construction series. These results suggest that using the series in level form to generate a forecast of new building construction costs would be inappropriate. That is, any event inducing in a shock or unexpected change to the series would be permanent. On the other hand, using some measure incorporating the first-difference or change (i.e., inflation rate) would be appropriate as shocks to the first-differenced series would be temporary and revert back to some long-run

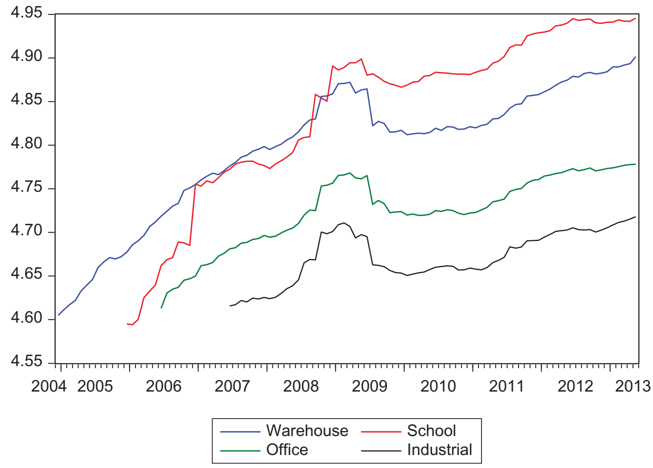

FIGURE 1 New construction PPI.

Notes. The sample period is December 2004 to May 2013 for 102 monthly observations for (log-level) new warehouse building construction producer price index, *Warehouse*. The sample period is December 2005 to May 2013 for 90 monthly observations for (log-level) new school building construction producer price index, *School*. The sample period is June 2006 to May 2013 for 84 monthly observations for (log-level) new office building construction producer price index, *Office*. The sample period is June 2007 to May 2013 for 72 monthly observations for (log-level) new industrial building construction producer price index.

TABLE 1 Unit root tests

	ADF	DF-GLS	PP	KPSS
Industrial	−2.533	−2.085	−2.061	0.100
Δ*Industrial*	−3.383**	−3.411***	−7.926***	0.081
Warehouse	−2.574	−1.476	−2.253	0.239***
Δ*Warehouse*	−3.063**	−2.553**	−9.972***	0.378*
School	−2.351	−0.887	−2.336	0.245***
Δ*School*	−3.678***	−3.427***	−10.380***	0.464**
Office	−2.618	−1.905	−2.613	0.168**
Δ*Office*	−2.764*	−0.694	−9.626***	0.268

Notes. The (adjusted) sample period is December 2004 (January 2004) to May 2013 for 102 (101) monthly observations for (log-level) new warehouse building construction producer price index, *Warehouse*. The (adjusted) sample period is December 2005 (January 2006) to May 2013 for 90 (89) monthly observations for (log-level) new school building construction producer price index, *School*. The (adjusted) sample period is June 2006 (July 2006) to May 2013 for 84 (83) monthly observations for (log-level) new office building construction producer price index, *Office*. The (adjusted) sample period is June 2007 (July 2007) to May 2013 for 72 (71) monthly observations for (log-level) new industrial building construction producer price index, *Industrial*. Δ denotes the first difference operator. Lag lengths were selected based on Schwarz information criterion. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

mean. The transitory feature of the filtered (first-differenced) series is desirable in forecasting models. As such, this feature would provide contractors and suppliers with more accurate measures to build in escalation allowances.

Since new construction price changes (or inflation rates) are stationary, using historical averages for forecasting or predicting future cost estimates would be appropriate. However, construction and project managers also should be interested in determining the appropriate historical (i.e., past) time horizon to use for planning purposes (in order to capture the mean-reverting behavior). That is, does the application of an historical average of the stationary first-differenced series depend on how long the effects of unexpected changes (i.e., shocks) last? We address this important question by estimating an autoregressive (AR) model for each new construction PPI inflation or growth rate. Using standard Box–Jenkins techniques (Box and Jenkins, 1976), the order of the AR model is 3 for each cost series (that is, three lags of the first-differenced series are used to predict the current value of the PPI inflation rate). We then simulated a one standard deviation shock to each series and measured the response from the series long-run historical average. This approach allows us to examine how long it takes for the shock to dissipate fully. Figure 2 plots the responses for each first-differenced cost series from a one standard deviation unexpected change. The dashed lines represent 95% confidence intervals and thus the statistical significance of the response. Interestingly, in each case, a shock to the new construction PPI inflation rate fully dissipates after 8 months. However, three of the four new construction PPI inflation rates tend to fluctuate some before the shock fully dissipates. The exception is new school

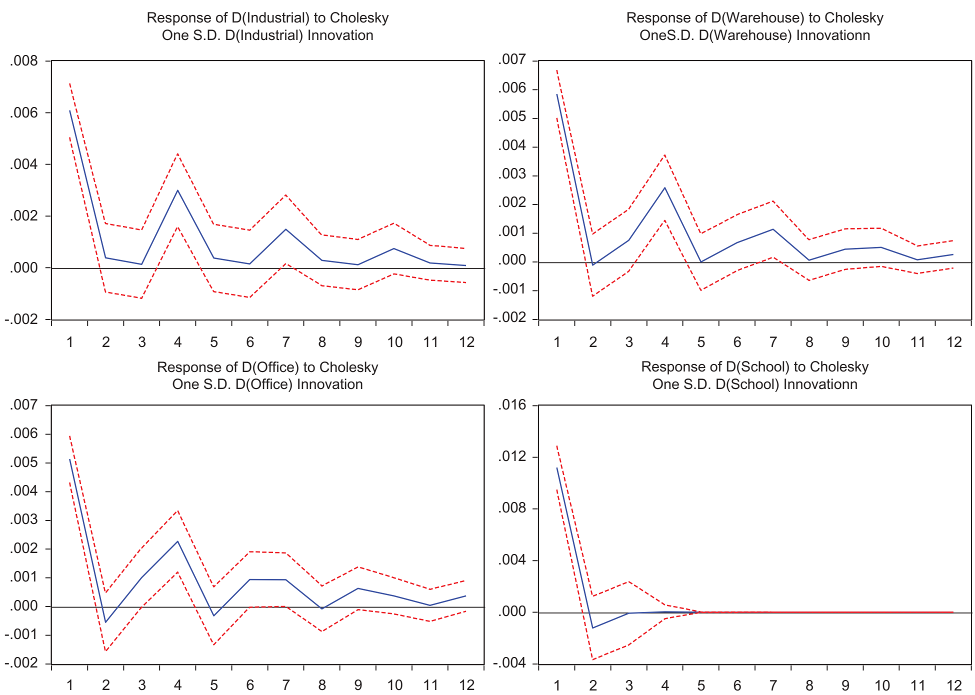

FIGURE 2 Impulse responses to one standard deviation shock.

Notes. Impulse responses are computed from the estimation of an autoregressive model. The dashed lines are confidence intervals that indicate the statistical significance of the response. The horizontal axis shows the forecast horizon measured in months from the time of the shock, while the vertical axis measures the size of the shock.

construction PPI inflation rate, which fully dissipates after 1 month. Perhaps this latter finding is attributable to the influence from projects of public institutions that often are relatively more constrained in building than private sector establishments comprising the other construction cost sectors. Specifically, many (public) schools obtain financing for current enrollment levels and are prohibited (to some degree) from building for future increases in size. This constraint, along with the lack of complexity and novelty usually associated with school construction projects relative to other new building construction projects, may better mitigate the unexpected construction cost increases (Shenhar & Dvir, 1996, 2007).

Concluding Remarks

Changes in construction costs over the life of a project have resulted in the use of escalation clauses in contracts. To date, however, no study has provided insights about the proper specification of the series used to determine new construction cost increases. We address this important issue by examining the time series properties of several BLS PPI construction cost series. The results suggest that these cost indicators are non-stationary and thus must be first-differenced in order to be used appropriately in forecasting and modeling of building cost inflation. The results hold for each of the four PPI series examined, namely, office, school, warehouse, and industrial, and thus apply to a wide range of projects. Moreover, having offered evidence about the appropriate use of historical averages in contracts and forecasting applications, we provide useful information as to the length of time necessary for stationarity to set in, that is, for a shock to the cost series to dissipate. These contributions fill a void in the existing literature and have practical implications for project managers and forecasters.

Future work could include using these results to examine different forecasting models to develop better costs estimates. Likewise, forecast comparisons could be made between different univariate models as well as multivariate models that include macroeconomic factors. Additionally, this approach to examining the time-series behavior of costs series to develop better forecasting models could be used in a variety of different sectors. For example, escalating health-care costs could be built into various contracts between physicians and insurance companies.

Note

1. See Elliott et al. (1996) for further discussion of the detrending procedure.

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