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Correlating the chemical engineering plant cost index with macro-economic indicators

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ABSTRACT

The chemical engineering plant cost index (CEPCI) is widely used for updating the capital costs of process engineering projects. Typically, forecasting it requires twenty or so parameters. As an alternative, we suggest a correlation for predicting the index as a function of readily available and forecast macro-economic indicators:

$$\mathrm{CEPCI}(n) = 0.135 \times \mathrm{CEPCI}(k_0) \times \exp\left\{A \times \sum_{k=k_0}^{n} i_k\right\} + B \times P_{\mathrm{oil}} + C,$$

with k_0 the first year of the period under consideration, i_k the interest rate on US bank prime loans in year k, and P_{oil} the US domestic oil price in year n. Best fit was obtained when choosing distinct sets of values of the constants A, B and C for each of the three periods 1958 to 1980; 1981 to 1999; and 2000 to 2011. These changes could have resulted from the impact of the oil shocks in the 1970s and very high interest rates in the 1980s, which perhaps heralded changes to the index formula in 1982 and 2002. The error was within 3% in any year from 1958 to 2011, and within 1% from 2004 to 2011 after readjusting the weighting of the price of oil. The correlation was applied to forecast the CEPCI under different scenarios modelled by the Energy Information Administration or predicted from oil futures contracts.

Keywords: Chemical engineering plant cost index; Capital cost estimates; Price of oil; Interest rates; Inflation; Plant cost index forecast

1. Introduction

1.1. *The chemical engineering plant cost index*

Process engineers often require to forecast or update the capital cost of new plants as a function of historical data on plants that were previously built or current costs. Cost indices are available for estimating the escalation of costs over the years, from a year m where the known or estimated cost is C_m and the index takes the value I_m, to a year n where it is C_n and the index takes value I_n. the projected cost in year n is then

$$C_n = (I_n/I_m) \times C_m \quad (1)$$

Several indices are available to the process engineer; for example the Nelson–Farrar refinery cost index published in the *Oil&Gas Journal* is widely used in the oil and gas industry; the Marshall and Swift equipment cost index, which was published monthly in *Chemical Engineering* until April 2012 and is now made available online (Marshall & Swift/Boeckh, LLC, 2013) is intended for the wider process and allied industries (chemicals, minerals, glass, power, refrigeration etc.); and the process engineering plant cost index published by the UK monthly *Process Engineering* provides data not just for the UK but also for 16 other OECD countries.

However, it seems that the best known process plant cost index worldwide is the chemical engineering plant cost index (CEPCI), which has appeared every month in the publication *Chemical Engineering* since 1963. Although it is primarily based on US cost data, the relative lack of local and specialised cost indices for the process industries amongst the countries in the world (according to The Institution of Chemical Engineers, 2000) might explain its widespread adoption. The dominance of the US$ as an international currency has also favoured the use of an index based in the US. Often, the CEPCI is used alongside a location factor to transpose the estimate from one country to another.

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The CEPCI is a composite index, made up from the weighted average of four sub-indices, and currently calculated from the following equation:

$$CEPCI = 0.50675\,E + 0.04575\,B + 0.1575\,ES + 0.290\,CL \quad (2)$$

where E is the equipment index, B is the buildings index, ES is the engineering and supervision index, and CL is the construction labour index (Vatavuk, 2002).

The equipment index E itself is in fact a weighted average of seven components, including: Heat exchangers and tanks; process machinery; pipes, valves and fittings; process instruments; pumps and compressors; electrical equipment; structural supports and miscellaneous.

In turn, each sub-index is the weighted average of sub-indices, derived from monthly Producer Price Indices (PPIs, that are compiled by the US Department of Labor's Bureau of Labor's Statistics (BLS) from about 100,000 price quotations issued by about a quarter as many domestically producing companies. Sub-indices or components for which labour costs have a significant influence are discounted by multiplying their labour cost component by a productivity factor (calculated from an average yearly increase of 2.2% in productivity since 2002). Baselines are taken as values of 100 in 1957–1959 for the composite CEPCI and all four sub-indices (Vatavuk, 2002). Finally, although the CEPCI underwent overhauls in 1982 and 2002 which affected the selection of PPIs, the productivity factor and the weighting coefficients in Eq. (2), it remained unchanged in its basic form and adjustments were made to provide revised indices in years prior to the changes (Vatavuk, 2002).

1.2. *Forecasting the chemical engineering plant cost index*

1.2.1. *Micro-economic approach*

The composite make-up of the CEPCI suggests that forecasting it requires a piecemeal approach to each of its four components as per Eq. (2), given that each component is likely to respond differently to factors such as inflation on raw materials, productivity gains, labour costs, etc. In turn, each component could be disaggregated into the relevant sub-indices from which it is made. However, when taken too far, this disaggregation can become difficult. All 53 PPI inputs would require tracking and forecasting, not to mention the added inconvenience that at times some of the PPI components can be modified or even discontinued by the BLS.

These difficulties would suggest using a reduced number of sub-indices as proxies for the whole set. This 'micro-economic' approach was first advocated by Caldwell and Ortego (1975), who proposed a surrogate index that could track the CEPCI by using only five BLS indices: four wholesale price indices (metal tanks; general purpose machinery and equipment; electrical machinery and equipment; and processing materials and components for construction), and one chemical engineering labour index. Earl (1977) found that Caldwell and Ortego's index failed to keep up well with historical data after 1974, and advocated a more disaggregated approach. He kept the main sub-indices and their respective weightings in the CEPCI but substituted 24 variables for the 70 or so that the CEPCI was then using. Importantly, he selected the 24 proxy variables from those amongst the BLS's PPIs for which both historical records and forecasts were available. This basic approach appears to have been retained in modern practice: for example Hollmann and Dysert (2007) quoted that in their experience, no more than 20 or so relevant proxies are applicable to estimating cost escalation of a process plant.

1.2.2. *Macro-economic approach*

As an alternative to the disaggregation method, straightforward prediction of the CEPCI from more general economic indicators on the cost of materials and labour could also be attempted. Cran (1976) suggested two component indices as effective proxies for major construction engineering indices, including the CEPCI. The two indices that he proposed tracked the costs associated with steel and labour respectively, with the proxy index a weighted average of the two. He found that the resulting index was following the CEPCI pretty closely. However, these correlations may then become too simplistic to withstand major changes in technology, productivity, market or other macroeconomic factors. In the same year as Cran's paper, Styhr Petersen and Bundgaard-Nielsen (1976) observed that his two-component index could not account for productivity gains in assembling plant components, leading to an overestimate for the capital cost of plants in Western Germany between 1973 and 1975. Nevertheless, Cran's approach was followed by the PEI index, which was published by the journal *Process Economics International* for 36 countries, and formerly called the engineering and process economics (EPE) index. Styhr Petersen and Bundgaard-Nielsen also suggested that any other multi-component indices would be affected in a similar manner, including the CEPCI.

Nevertheless, the idea that wider macro-economic data can be the sole input parameters is attractive because of the wide availability of data and forecasts for these. In fact, the wider economic activity is not just indicated by the cost of materials and labour as in Cran's model, but can be linked with more general indicators. This type of approach seems to have been initially advocated by Caldwell and Ortego (1975), as an alternative to their own micro-economic approach. They found that simple linear correlations held between the CEPCI and any of the following: the gross national product deflator; the consumer price index; the wholesale price index; and other price indices. In all cases the slope of the correlation was close to 1. However, they observed that the actual values of the CEPCI significantly swung cyclically above and below the values predicted by those simple linear correlations. Since then, literature on the topic of correlating the CEPCI with macro-economic indicators appears extremely scarce. A more recent example that we found regarded the Nelson–Farrar refinery cost index rather than the CEPCI, but it evidenced again the type of difficulty Caldwell and Ortego faced when trying this type of approach: Parker (2008) presented a graph where he plotted the fuel cost index against the construction cost index of the Nelson–Farrar refinery cost index from 1930 to 2007. While on a logarithmic scale the construction cost index seemed to be a broadly linear function of the fuel cost index with a slope of 1.00, there were wide swings away from this parity ratio, with vertical and horizontal segments indicating periods of rapid surges and drops of one factor apparently independently from the other. The two indices were correlated to some extent, but they were visibly subject to different influences too.

In fact, econometric methods have been developed since the 1970s outside the field of engineering that more generally model economic variables. A good introduction to these methods for the non-specialist can be found in Koop (2000). Of critical importance to these methods is a rigorous handling