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Final Report

CONSTRUCTION COST FORECAST MODEL

MODEL DOCUMENTATION AND TECHNICAL NOTES

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16. Abstract

Construction cost indices are generally estimated with Laspeyres, Paasche, or Fisher indices that allow changes in the quantities of construction bid items, as well as changes in price to change the cost indices of those items. These cost indices, while useful in forecasting the near-term costs of construction contracts for projects that have been designed and are about to be let, are not good indicators of price inflation in highway construction. This report contains the documentation and supporting technical notes for a statistical model that estimates changes in the price components of the Colorado Construction Cost Index. The model contains two specifications. In the first, the composite construction index is a function of the producer prices of inputs: oil, concrete, steel, labor and equipment. In the second, the composite construction index is a function of the price of oil, wages and nationwide demand for construction services.

Implementation

The model has been transferred to CDOT's economist, who will maintain and operate it to forecast price inflation in construction costs over a thirty-year period, in support of statewide planning and programming.

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Table of Contents

I. Model Operating and Maintenance Instructions

A. Understanding the Model

This section describes the purposes for which the model's outputs are appropriate and provides a basic outline of the model's structure. It will be of interest to all who will operate the model, maintain it or use its results.

1. Purpose of the Model

The model estimates the changes in the costs of the highway construction program administered by the Colorado Department of Transportation (CDOT). The output of the forecasts is the percentage change in the composite Colorado Cost Construction Index (CCCI) each calendar quarter that are due to changes in price, rather than to changes in quantity.

The CCCI is an imperfect measure of the prices of highway construction because its values are influenced equally by the quantities of the items used in construction and by the price of those items. Changes in construction cost item quantities have the direct effect of changing the weights used in the index calculations, such that the Colorado Construction Cost Index will change, even if the unit prices of all of the construction cost items were to remain the same. The changes in quantities also have an indirect effect—economies of scale. Unit costs that are bid for smaller bid volumes of a commodity are likely to be higher than unit costs that are bid for larger volumes when the underlying price of the commodity is the same. These weighting and scaling problems, which are intractable in any kind of index, are discussed in detail in section II.A below.

The model does not forecast economic conditions; rather, the model depends on macroeconomic and demographic forecasts as inputs from which it estimates highway construction costs in Colorado.

2. Specifications in the Model

The model estimates revenues and the activities that underlie them, called *dependent variables* in this document, as functions of other variables, called *independent variables*. Such independent variables typically describe the population, the economy, and other factors that are expected to influence transportation revenues. Any model that forecasts a dependent variable as a function of independent variables is a *structural model*.

The general form of the causal variable model is:

$Y = f(X_1, X_2, \ldots X_i)$

Where:

Y = the value of the dependent variable; and

X_i = the value of the each independent variable.

To attempt to disentangle changes in the Colorado Construction Cost Index due to price from changes due to quantity, the forecasting model contains two different specifications.

A specification based on input prices:

$$CCH_{con} = f(P_{oil}, P_{cement}, P_{steel}, P_{equipment}, W)$$

And a specification based on input prices and the overall demand for construction:

$$CCH_{con} = f(P_{oil}, W, CNC_{con})$$

In which:

CCH_{con}	=	The value of highway construction in Colorado.
P_X	=	The traded spot price of commodity "X" in U.S. markets.
W	=	Average wages in the Colorado construction industry.
CNC_{con}	=	The value of all types of construction in the United States.

Neither of the specifications is entirely satisfactory: both specifications have the value of construction, rather than the price of construction, as their independent variable, since price changes cannot be disentangled from quantity changes in the CCCI. Neither specification can estimate the price elasticity of supply in highway construction, and the price-based specification does not include any direct effects of demand. The shortcomings of the specifications are described in section III.B below.

3. Functional Forms

The CDOT revenue model contains several statistical models that estimate the values of b_i that are used with forecast values of the independent variables X_i to estimate the dependent variable Y in future years. Each of these statistical models uses ordinary least squares (OLS) regression to estimate the values of b_i in a linear equation:

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots + b_iX_i + \varepsilon$$

Where:

b_0 = the value of y when the values of all independent variables X_i are zero, i.e. the X-intercept of the function; and

ε = that portion of the value of y that is not explained by the values of the independent variables X_i, i.e. the error term.

This form implies a simple linear relationship between each independent variable X_i and the dependent variable Y. Where economic theory or intuitive good sense indicates that the relationship should not be linear, the functional forms of the relationships are transformed into linear forms before being estimated with an ordinary least squares regression. Both of the specifications are modeled in log-linear form, i.e.

$$\ln(CCH_{con}) = b_0 + b_1\ln(P_{oil}) + b_2\ln(P_{cement}) + b_3\ln(P_{steel}) + b_4\ln(P_{equipment}) + b_5\ln(W) + \varepsilon$$

And

$$\ln(CCH_{con}) = b_0 + b_1\ln(P_{oil}) + b_2\ln(CNC_{con}) + b_3\ln(W) + \varepsilon$$

B. Updating the Model

This section describes the procedures for keeping the model current as each quarter passes. It will be of interest to those who will operate and maintain the model.

1. Converting a Year from Forecast to Actual

All of the model worksheets contain historical information up to the most recent quarter for which actual data are available. The quarter after that quarter is the first forecast year. As each quarter passes by, the forecasts and assumptions that the model estimates in the first forecast quarter are to be replaced with the actual data for that quarter.

The model updates its forecast by replacing forecast data for revenues in the base quarter **t-1** with actual data for that quarter. If **t-1** was the first forecast quarter in the prior run of the model, and actual data has since become available for the quarter **t-1**, then the model replaces the previously forecasted values with actual data.

Once the actual values for the quarter **t-1** have replaced the values forecast in the prior run, the model will forecast of all following quarters **t, t+1**, **t+2**, ... **t+n** by basing them from the actual values for **t-1** that have been inserted. By doing nothing other than replacing the forecasts with actual data for year **t-1**, all of the forecasts are to be updated.

PROCEDURE: INSERTING ACTUAL DATA

Actual data for dependent variables must be inserted in the following locations:

Worksheet	*Cells to Update*
Dependent Variables	Appropriate quarter column; rows 2, 5
Independent Variables	Appropriate quarter column; rows 3:7, 9
Construction Spending	Appropriate month row; column E

All of the data sources are identified in the worksheets.

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2. Changing Forecasts of Independent Variables

The model operator should update the forecasts of the following independent variables, all of which are available within the Moody's macroeconomic forecast service to which CDOT subscribes.

	Historical Series ID	*NAICS or SOC*	*Moodys' Nmenomic*	*Description*
Producer Prices				
BLS	PCU2111112111111	211111	FXPPIFU61.US	Crude Petroleum
BLS	PCU327310327310	32731	FXPPINM22.US	Cement Manufacturing
BLS	PCU331110331110	33111	FXPPIME1.US	Iron & Steel Mills Producer Price Index
BLS	PCU333120333120	33312	FXPPIMA2.US	Construction Machinery and Equipment
BLS	EEU20000051	200	FAHE23.US	Avg. Hourly Earnings: Construction
Demand				
BOC	EC0723	23	FCPTC.US	Value of Construction Put in Place
Notes				
NAICS	*North American Industrial Classification System*			
SOC	*Standard Occupational Classification*			
BLS	*Bureau of Labor Statistics*			
BOC	*Bureau of the Census*			

PROCEDURE

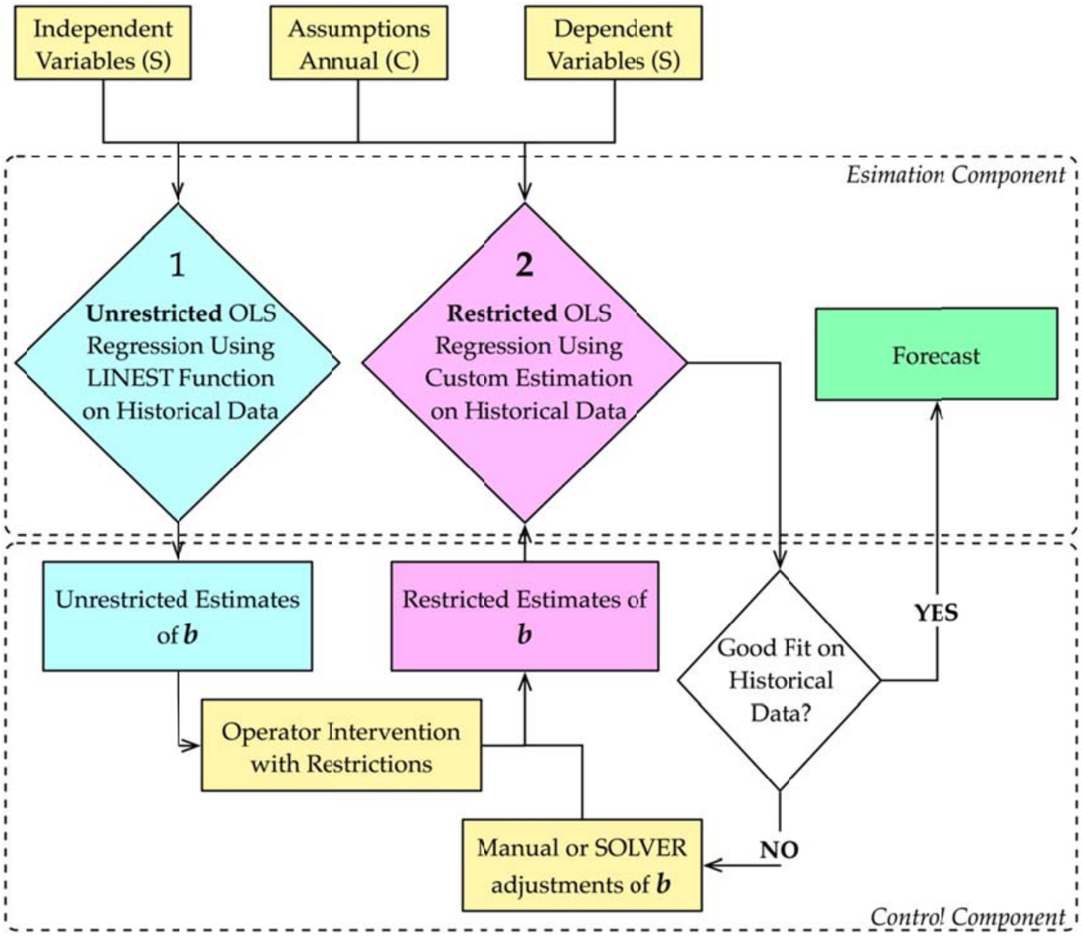
Current forecasts for the independent variables must be inserted in the following locations:

Worksheet	*Cells to Update*
Independent Variables	Appropriate quarter column; rows 3:7, 9

3. Changing OLS Coefficients

All of the statistical models are designed with the same key components, which are described in the exhibit below:

Exhibit 1: General Layout and Function of OLS Components



The OLS component works in two stages, each of which is a computation that is completely separated from the other:

1. The LINEST function estimates the unrestricted values of the coefficients, $\boldsymbol{b_i}$, along with several measures of the goodness of fit: the F statistic, the unadjusted R^2, and the standard error and t-statistic for each coefficient.
2. CDOT staff chooses, either manually or by using the SOLVER function, a set of coefficients $\boldsymbol{b_i}$ that feed into a custom-built OLS estimator. This custom estimator does not itself estimate coefficients, but does produce several measures of the goodness of fit for the coefficients that are fed into it.

The purpose of the two-stage layout is to provide CDOT staff with initial estimates of the coefficients $\boldsymbol{b_i}$ that are the best, linear, and unbiased (BLU) estimates. CDOT can then manipulate those initial estimates by dropping variables or adding restrictions, watching how their manipulations affect the goodness of fit. There is no connection between the two stages of the model, other than CDOT staff referring to the estimates produced in the first stage as they manipulate variables and restrictions in the second stage.

The second stage also calculates a forecast of $\boldsymbol{Y}$, using the coefficients $\boldsymbol{b_i}$ that are fed into it every time the model is run. As CDOT staff manipulate the coefficients $\boldsymbol{b_i}$ in the second stage to find an acceptable goodness of fit with the historical data, the model also alters the forecast.

The estimation component of the price-based specification of the model is located in the 'OLS Prices' worksheet and the estimation component of the demand-based specification of the model is located in the 'OLS Demand' worksheet. The control components both OLS models are contained in the worksheet 'Solver.' The control component for an OLS regression consists of a table that contains the coefficients estimated in the first stage, a control space in which the coefficients for the second stage are manipulated, and a reporting space, in which the goodness of fit for the second-stage coefficients are displayed. An example is exhibited below.

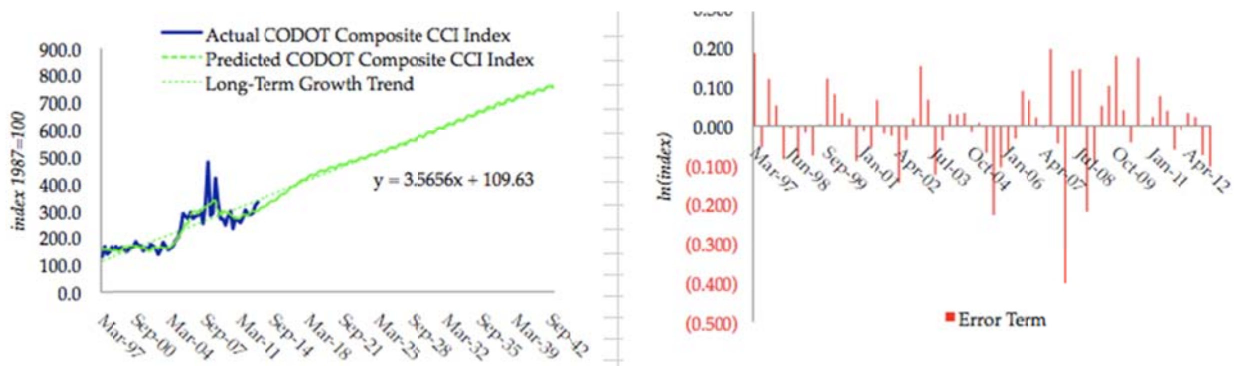
Exhibit 2: Table in Control Component of Price-Based OLS Model

◇	A	B	C	D	E	F
1		*lag*	**ln(CCI) = ln(PPI)**	***LINEST (unrestricted)***	*Solver*	*t-statistic*
2	b_0		intercept	(5.4665)	(5.4665)	
3	b_1	0	ln(Crude Petroleum PPI)	0.1364	0.1364	16.24
4	b_2	0	ln(Cement Manufacturing PPI)	1.2811	1.2811	44.35
5	b_3	0	ln(Iron & Steel Mills PPI)	0.0500	0.0500	2.37
6	b_4	0	ln(Construction Machinery and Equipment PPI)	1.3259	1.3259	13.98
7	b_5	0	ln(Avg. Hourly Earnings: Construction)	(1.1540)	(1.1540)	(17.72)
8	$\sum e^2$		squared error	6.80E-01	6.80E-01	
9			unadjusted R^2	0.892		
10			adjusted R^2			
11			mean APE		7.6%	
12			(n-1)		64	
13			(n-k)	58		

The first stage OLS regression reports its BLU estimates of the unrestricted coefficients $\boldsymbol{b_i}$ in column C. Two of the goodness of fit measures calculated in the first stage, unadjusted R^2 and $\sum e^2$, are reported in cells D8 and D9. CDOT staff then enter coefficients into the control cells E2:E7. These coefficients can equal those estimated in the first stage, a set of coefficients that is optimized by the SOLVER function or any other set of coefficients.

The goodness of fit statistics shown in cells D9:D11 and in E3:I7 are used by CDOT staff to determine whether the second set of coefficients is adequate (i.e., sufficiently close to the goodness of fit achieved in the first stage OLS regression). To provide further information that CDOT staff can use to assess the goodness of fit in the second stage regression, the control component of each OLS regression includes two graphs to the right of the control table: the first graph compares the actual values and the estimated values of the dependent variable, and the second graph displays the error term (i.e., the difference between the actual and estimated values of the dependent variable in each year). An example of each of these graphs is exhibited below.

Exhibit 3: Goodness-of-Fit Graphs in the OLS Models



In the second stage OLS regression, CDOT has the option of using the SOLVER function to choose coefficients. To use the SOLVER in this manner, it must be configured to minimize the value of the target cell and the target cell must be the sum of squared errors, $\sum e^2$, in the control space. In the control table example above, the target cell is E8. The solver must also be configured to alter the values of the coefficients, cells E2:E7 in the example table above, with any restrictions that are specified by CDOT staff. The SOLVER function will converge on any solution that meets the convergence criteria, not just on the one set of coefficients that are BLU estimates. It is possible that the solver will return estimates of the coefficients that are quite different than those estimated in the first stage of the OLS regression and that CDOT should not accept any second stage estimates generated by the SOLVER function that do appear to be consistent with the estimates of the first stage.

4. Lagging Independent Variables

The model provides the ability for CDOT staff to test lagged independent variables. Introducing a lag into an independent variable directs the model to take into account a specified passage of time before an independent variable affects the dependent variable. In the case of this model, such a lag implies that the cost of construction in a quarter is determined input prices or construction demand not in that quarter but in a prior quarter.

CDOT staff can control the lag of each independent variable in each specification of the model by entering the number of quarter by which the variable should be lagged by entering digits into column B of the 'Solver' worksheet. The digit "1" directs the model to regress the construction cost index in each quarter on the independent variable's value one quarter prior. The digit "2" directs the model to regress the construction cost index in each quarter on the independent variable's value two quarters prior, and so on. The values in the cells that control the lags are restricted to whole numbers between 0 and 4, which allows lags no longer than one year.

II. Technical Notes

A. Approach

The construction cost forecast model is a structural model, in which the cost of a construction item, a *dependent variable* in this document, is a function of the prices of its constituent elements, called *independent variables*. The general form of a structural model is:

$$Y = f(X_1, X_2, \dots X_i) \quad \text{Equation 1}$$

Where:

Y = the value of the dependent variable; and

X_i = the value of the each independent variable.

1. Prices, Quantities, and Values

The construction forecast model incorporates a basic accounting entity that value, or cost, of any item or element is a product of its unit price and the quantity of units (i.e., ***V=PQ***). In the case of the cost of a construction project, it is the sum of the costs of its bid items included in the project, and the unit price of each item is the bid cost of the item, divided by the quantity of the item:

$$V_y = (V_{x1}) + (V_{x2}) + \dots + (V_{xi}) + \dots + (V_{xn}) \quad \text{Equation 2}$$

$$P_yQ_y = (P_{x1}Q_{x1}) + (P_{x2}Q_{x2}) + \dots + (P_{xi}Q_{xi}) + \dots + (P_{xn}Q_{xn})$$

$$P_y = \frac{(P_{x1}Q_{x1}) + (P_{x2}Q_{x2}) + \dots + (P_{xi}Q_{xi}) + \dots + (P_{xn}Q_{xn})}{Q_y}$$

V_y = cost of the construction project, in dollars

P_y = weighted average unit price, or cost index, of the project

Q_y = weighted average of the quantities of bid items in the project

V_{xi} = the bid cost of construction item i

P_{xi} the unit price of construction item i

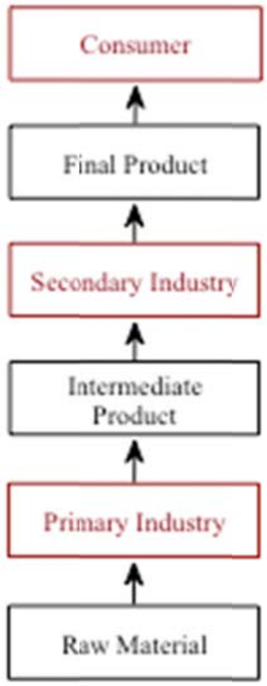
Q_{xi} the specified quantity of construction item i

This accounting entity of price, quantity, and value is simple in concept and it is directly applied by CDOT in the estimation of the CCCI: the cost of a highway construction project is the sum of the costs of each of the construction cost item that it specified in it.

2. Intermediate Products

The application of the ***V=P*Q*** accounting entity in the construction cost forecast model is complicated by the presence of intermediate products among the construction cost items. An intermediate product is an output from one industry that is used as an input by another industry.

Exhibit 4: Raw Materials, Intermediate Products and Final Products

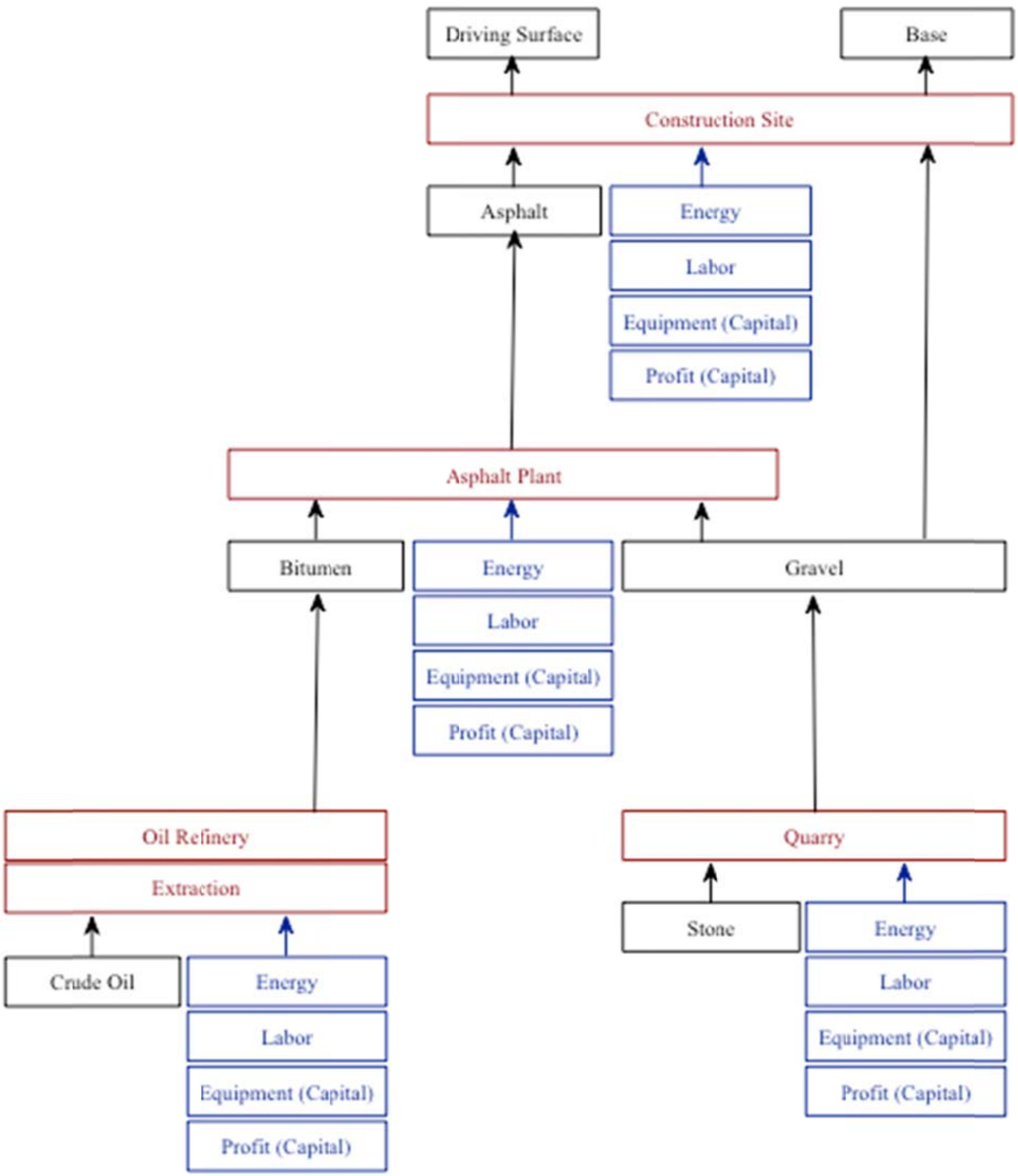


An intermediate product is more than a raw material since it results from combining inputs in an industry; neither is it a final product in that it is consumed in the production of other products. While Exhibit 4 above illustrates a simple case of only one secondary industry, the chain of inputs and outputs through the production of some final products can run through several secondary industries.

As one intermediate product is combined with others, so are the prices and quantities of the elements that comprise them. Shifts in the prices of raw materials and the prices of intermediate products will be reflected in shifts in the prices of final products – highway construction projects in this case. These relationships among prices of raw materials, intermediate products and final projects are important in understanding the costs of highway construction. These relationships are examined in section II.B below. However, shifts in the quantities of raw materials and intermediate products used in a final product will also be reflected in their unit prices if those unit prices are derived from the values of the products, i.e. $P = \frac{V}{Q}$. This is the norm in the Colorado Construction Cost Index, in which unit prices are derived from the bid costs of construction items and the mix of construction items, which are raw materials and intermediate products, varies significantly from one construction project to another.

In each industry, the input raw material or intermediate product is combined with other inputs – labor, energy and capital – to produce an input as is illustrated in Exhibit 5, the simplified example of a road comprised of a gravel base and an asphalt driving surface.

Exhibit 5: Simple Illustration of Intermediate and Final Products in a Road



All of the industries that contribute to the final product, the road, use some common inputs: labor, energy and capital. Each industry takes its inputs and adds value to them, which is reflected in the value of its output[1]. If we assume that the prices of labor, energy and capital are the same across all industries involved in making a highway then the price of that highway is a function of those prices and the prices of raw materials. In such a function, the prices of intermediate products can be ignored.

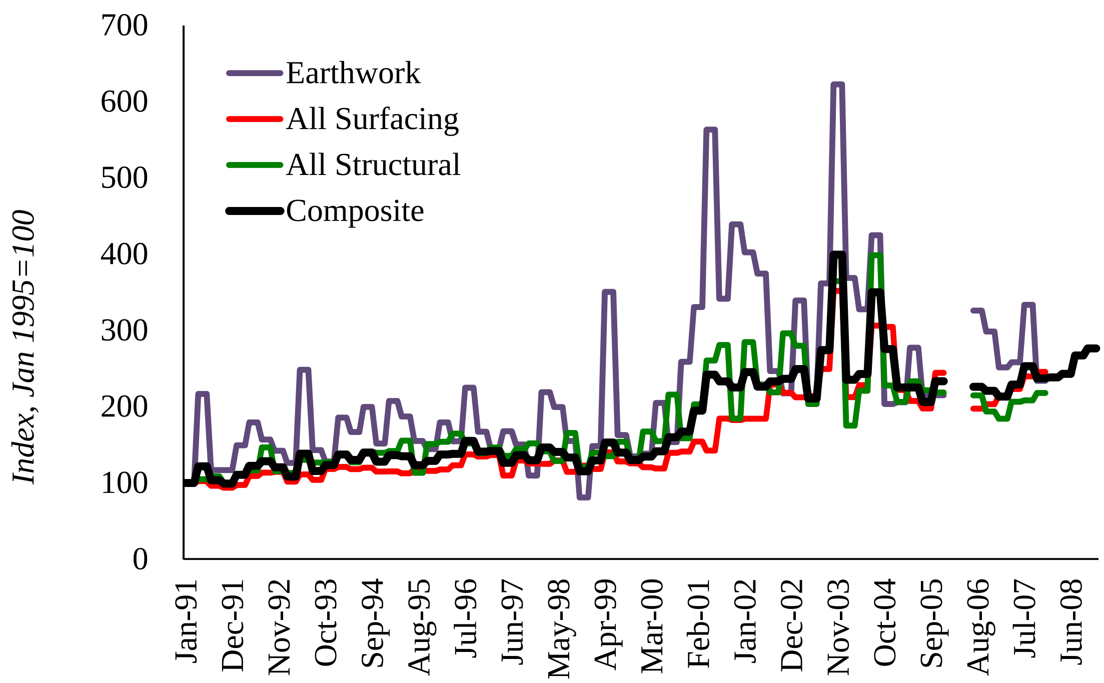
B. Historical Values of the Colorado Construction Cost Index

CDOT has published estimates of the Colorado Construction Cost Index by quarter since 1987 at three levels of aggregation:

- Six composites of commodities – earthwork, asphalt pavement, concrete pavement, structural concrete, reinforcing steel and structural steel – that fold into
- Three composites of work types – earthwork, surfacing and structural – that fold into
- One overall composite index.

These indices were calculated as Laspeyres indices until January 2012 and Fisher indices thereafter. Both indices are explained in appendix III.A below.

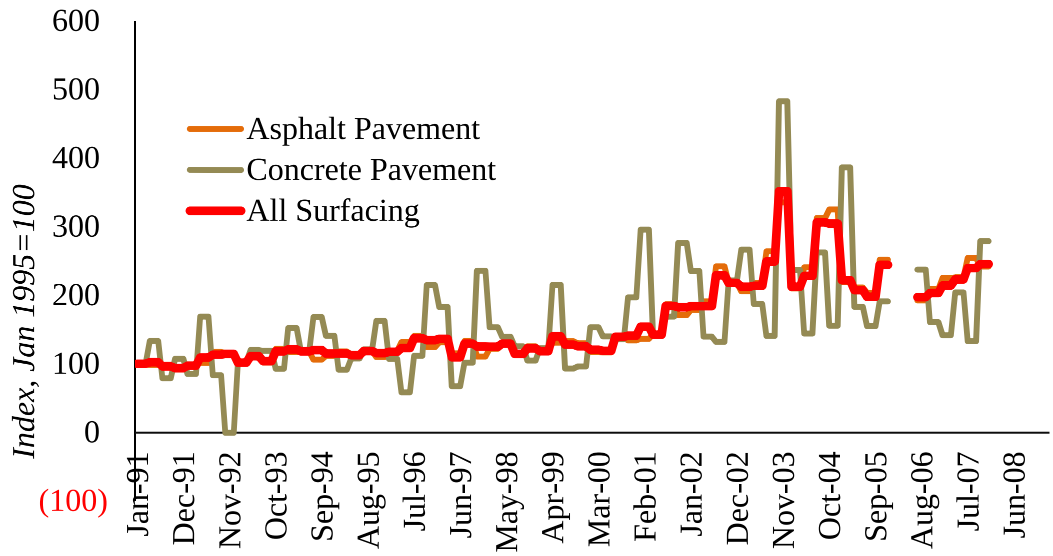
Exhibit 6: Summary Colorado Construction Cost Indices



[1] The value of an industry's output less the values of the raw materials, energy and labor used to produce that output is that industry's *value added*. Many nations tax value added instead of sales.

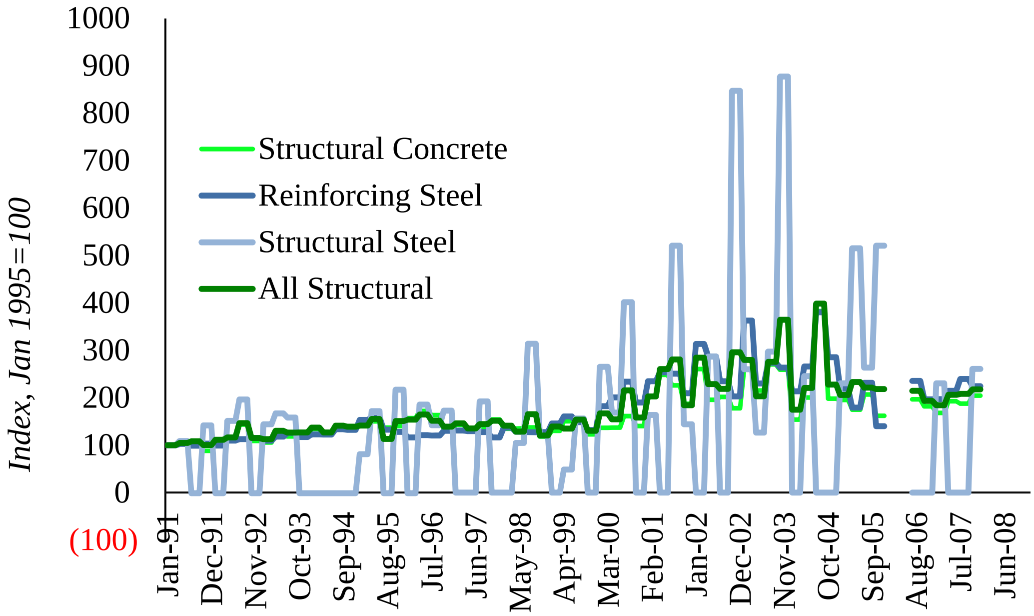
In the graphs throughout this section, the quarterly indices are plotted on a monthly scale with the assumption that each index is constant throughout the three months of each quarter. We have converted all indices to a base of January 1995 = 100 to allow their direct comparison.

Exhibit 7: Colorado Construction Cost Indices for Asphalt Pavement, Concrete Pavement and All Surfacing



We believe that index of all surfacing costs closely follows the asphalt pavement index because of the relatively small quantities concrete pavement used in Colorado.

Exhibit 8: Colorado Cost Indices for Structural Concrete, Steel and All Structural Work



The structural steel index shows one of the weaknesses of indices: the low absolute values of the unit prices result in large variations in their index. That the unit price for structural steel was often less than zero demonstrates one of the oddities of the bidding process: contractors may have used an artificially low price of structural steel to slightly inflate prices on another, more critical commodity on which they do not wish to reveal their true costs to their competitors.

C. The Markets for Highway Construction Commodities

In this section, we compare the Colorado construction cost indices for the principal commodities in highway construction – asphalt, concrete and steel – to other measures of the markets and prices for those commodities.

We use the producer price[2] indices (PPI) estimated by the U.S. Bureau of Labor Statistics (BLS) for these comparisons, rather than the ordinal market prices for these commodities. Our reason for doing so is consistency: the BLS PPI are surveyed, estimated and reported on the same bases as the data for wage costs published by the BLS and the data for inputs, outputs and earnings of each industry that are published by the U.S. Bureau of Economic Analysis (BEA) in the National Economic Accounts. By using the BLS and BEA data, we can be confident of the result of our analyses, which allows us to compare or combine these

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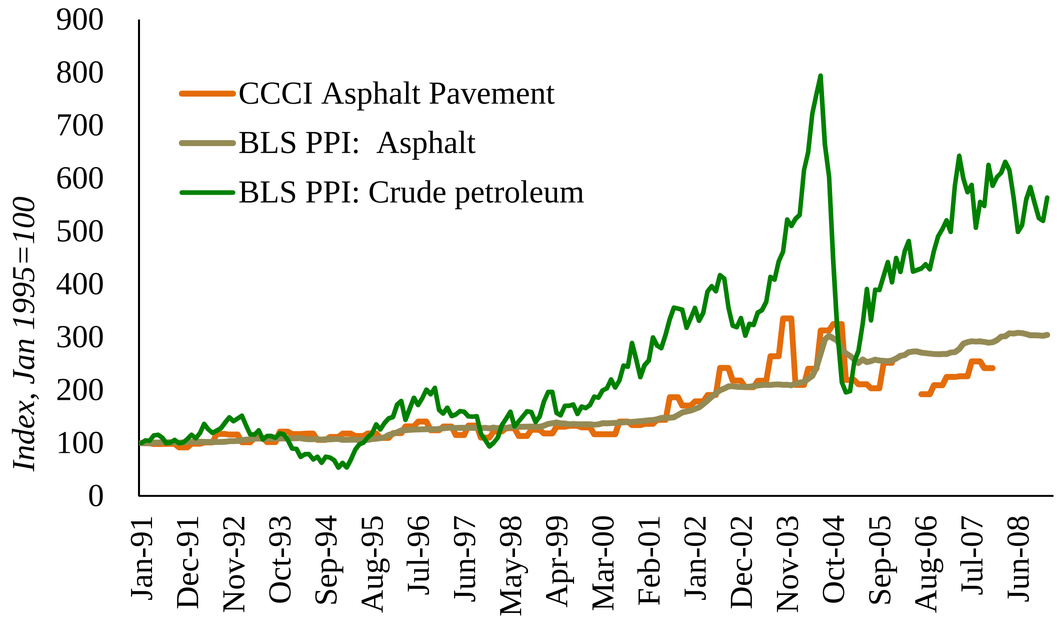
[2] Producer prices are the unit prices that the producers in each industry report that they have charged in the sale of their products. In each industry, all outputs sold are combined into a weighted average unit price with the entity $P = \frac{V}{Q}$.

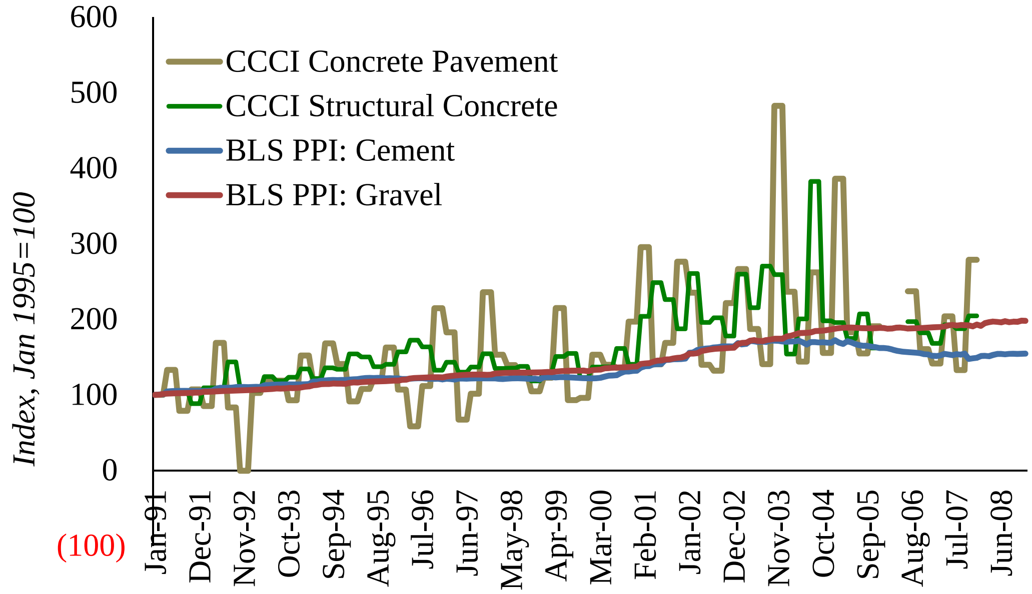
data. We can also be confident of the quality of the data, collected by the leading federal authorities in their collection and analysis.

Exhibit 9: Price Indices for Oil and Asphalt



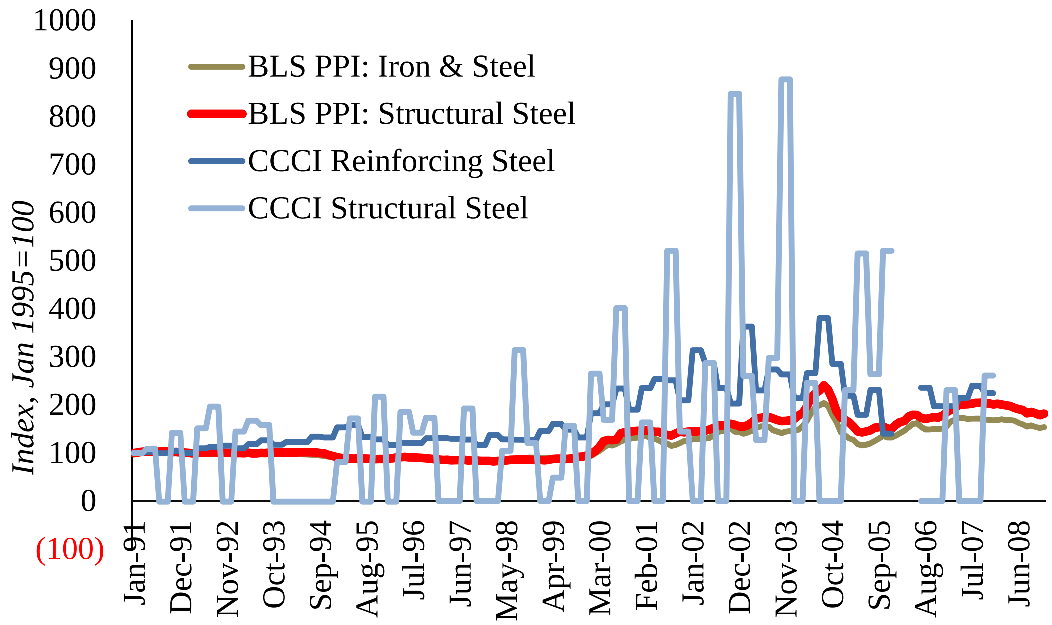
The Colorado cost index for asphalt paving closely follows the national average PPI for the asphalt industry. The producer price for the crude petroleum industry, i.e. the average selling price of crude petroleum from U.S. sources, shows more price volatility than asphalt, which we attribute to the relative stability of the prices of the other inputs into asphalt – labor, energy and capital. This provides a preliminary indication that changes in the input price of oil may not be as closely linked to the output price of asphalt as, the price of labor may be.

Exhibit 10: Concrete



The concrete market shows more variation between the BLS national average output price for cement and the Colorado cost indices for concretes. We do not put much stock in the concrete pavement index because the relatively small amounts involved.

Exhibit 11: Steel



We ignore the Colorado cost index for structural steel due to its low prices and relatively small volumes. The Colorado cost index for reinforcing steel seems to follow the national market prices of iron and steel ingots, the output of the first stage of steel smelting, and subsequently fabricated structural steel.

D. The Cost of Labor: Wages and Salaries

The costs of labor, both those paid by construction firms to its employees and sub-contractors, and those included in the costs of fabricated goods used in highway construction, will be passed on to CDOT in those firms' bids.

1. Definitions of Wages, Income Payroll Costs, and Costs of Labor

The wages paid to workers and the personal incomes earned by people and households are widely studied in economics; as a result, the U.S. government invests considerable effort in sampling and estimating those data. Neither wages nor personal incomes are, however, equal to the costs of labor. Rather, wages and salaries are the common base from which the total costs of labor to firms and the total incomes of persons are estimated.

The total cost of labor to a firm is the sum of:

- Direct costs of the employee: wages and salaries paid by the employer to the employee
- Indirect costs of the employee: training and "fringe benefits"—pension contributions, health insurance, and life insurance—funded by the employer but not paid to the employee
- Direct costs of the position: the cost of the time of one employee working in a position while another employee is sick, on vacation, or attending a training program
- Indirect costs of a position: include duty to accommodate injured or disabled workers plus the costs of child care programs, employee assistance programs, and regulated apprenticeship programs
- Overhead costs: include the costs of labor relations and human resources management

A study that we conducted in another jurisdiction found that the direct costs of employees (i.e., the wages or salaries paid to employees_ made up at most two-thirds of the total cost of labor incurred by highway construction firms.[3]

Similarly, wages and salaries make only part of the personal income our household income that is estimated and reported in regional, state, and national economic accounts. The other components of personal income are transfers from governments and incomes from investments: dividends, capital gains, and rents. In 2010, wages and

[3] City of Portland: Comparison of Pavement Cost Estimates. Dye Management Group Inc., 2008

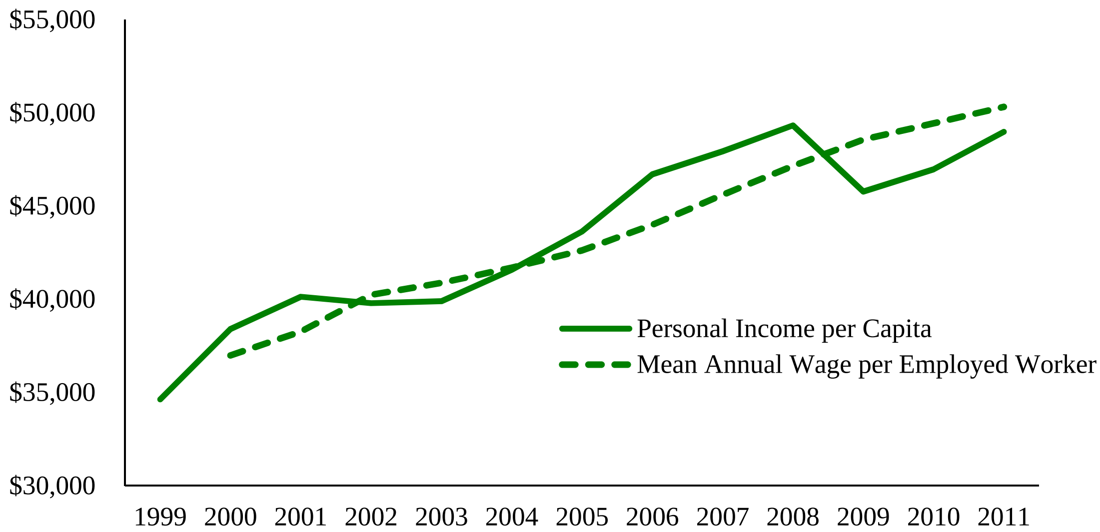
salaries made up slightly more than one-half of the personal income earned in the United States.[4]

Exhibit 12: Personal Income and Cost of Labor (Not to Scale)

Personal income is a poor proxy for the cost of labor, as it includes investment incomes and does not include indirect and overhead costs of labor that a highway construction firm would legitimately take into account when estimating the cost of a job. As the historical data for the Denver-Aurora area show, personal income is more volatile than wages because it includes the effect on investment earnings of events in financial markets, as well as markets for goods and services.

[4] U.S Bureau of Economic Analysis. National Income and Products Accounts Tables. Table 2.1. Personal Income and its Disposition. http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1#reqid=9&step=3&isuri=1&903=58

Exhibit 13: Personal Income and Wages in the Denver Area



Of the widely available data, wages and salaries are the better indicator of labor costs than are personal incomes.

2. Historical Data

The BLS surveys employers across the nation in two separate efforts: the Occupational and Employment Statistics (OES) and the National Compensation Survey (NCS). Of the two, the OES is the more appropriate source of wage data for estimating labor costs used to forecast construction costs.[5] The OES program estimates the number of people employed and their wages at levels of great detail.

- By occupation: over 3,000 occupations, each defined in the Standard Occupational Classification (SOC).[6] The SOC contains twenty-three major groups, of which one group (47-0000) is dedicated to the construction and extraction industries.
- By geographic area: 377 metropolitan statistical areas (MSAs) and 208 nonmetropolitan areas, aggregated for each state and for the nation.

Lists of the seven metropolitan areas and four non-metropolitan areas that comprise Colorado, along with the occupations relevant to highway construction that reported

[5] The OES program is the larger survey and can provide a greater range of occupations and areas. Only the OES has information on employment and wages for detailed occupations. The NCS survey is administered through a personal visit to each employer and it obtains data about wages for varying responsibilities and workloads within each occupation. Both surveys exclude agriculture, fishing and forestry industries, and private household workers. The OES program includes the U.S. Postal Service and the federal government, and the NCS program excludes the federal government. The OES estimates are available at www.bls.gov/oes/oes_data.htm and the NCS estimates are available at http://www.bls.gov/ncs/ocs/compub.htm.

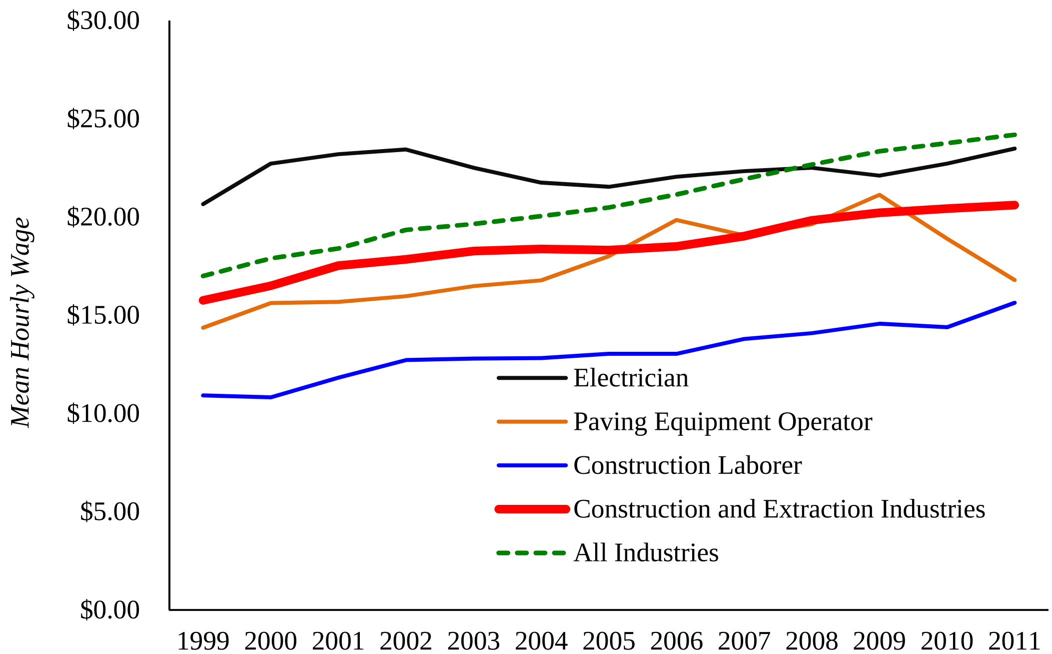
[6] http://www.bls.gov/soc

within those areas within the Construction and Extraction Industries Classification, are appended to the report.

The bureau conducts the OES survey semi-annually, and over a three-year period, samples about 60 percent of all employers in the nation.

OES estimates for three sample occupations in the construction and extraction industry group, the industry group as a whole and all occupations as a whole in the Denver-Aurora MSA, shown in Exhibit 14 below.

Exhibit 14: Mean Hourly Wages, Denver-Aurora Metropolitan Statistical Area



The OES data for the Denver-Aurora area show that through the most recent economic cycle of high growth from 2001 to 2008 and the subsequent downturn, mean wages grew modestly, but steadily, through the construction industry and the region's private sector economy as a whole.

3. Bacon-Davis Act

The federal Bacon-Davis Act requires that "contractors and subcontractors performing on federally funded or assisted contracts in excess of $2,000 for the construction, alteration, or repair of public buildings or public works" provide their workers with "locally prevailing wages and fringe benefits paid on projects of a similar character".[7]

[7] 40 U.S.C. 3141-3148. Signed into law in 1931, the intent of this Act was to prevent migrant labor being used to displace local labor on federal works projects.

The Act explicitly applies to federal-aid highway projects and the original job classifications of “mechanics and laborers”, along with their “apprentices, trainees and helpers” now encompass hundreds of job classifications.

Both the prevailing wages and the job classifications for which they apply are determined by the U.S. Department of Labor, which surveys[8] employers in each county of each state, then publishes its estimates in a series of general decisions. At present, there are eight general decisions specific to highway construction in Colorado, and one of these eight decisions applies to each of Colorado’s sixty-four counties. The current determination for the prevailing wages in highway construction occupations in Denver County is appended to this report.[9]

A general decision states for each job classification in each county what the Department of Labor deems to be the prevailing wage and value of fringe benefits. A contractor or subcontractor working on a federally funded contract must show, upon inspection by the Department of Labor, that the wages and fringe benefits they pay to their employees are equal to or greater than the prevailing wage and fringe benefits. In effect, the prevailing wages and fringe benefits are a floor below which actual wages and benefits cannot fall.

In the Denver area, at least, the mean hourly wage for three sample occupations estimated in the OES is consistently lower than the prevailing wage (excluding fringe benefits) determined in Bacon-Davis Act general decisions. While some deviation can be expected because of differences in geographical area and occupation,[10] we do not believe that the observed deviations could be fully explained by those differences.

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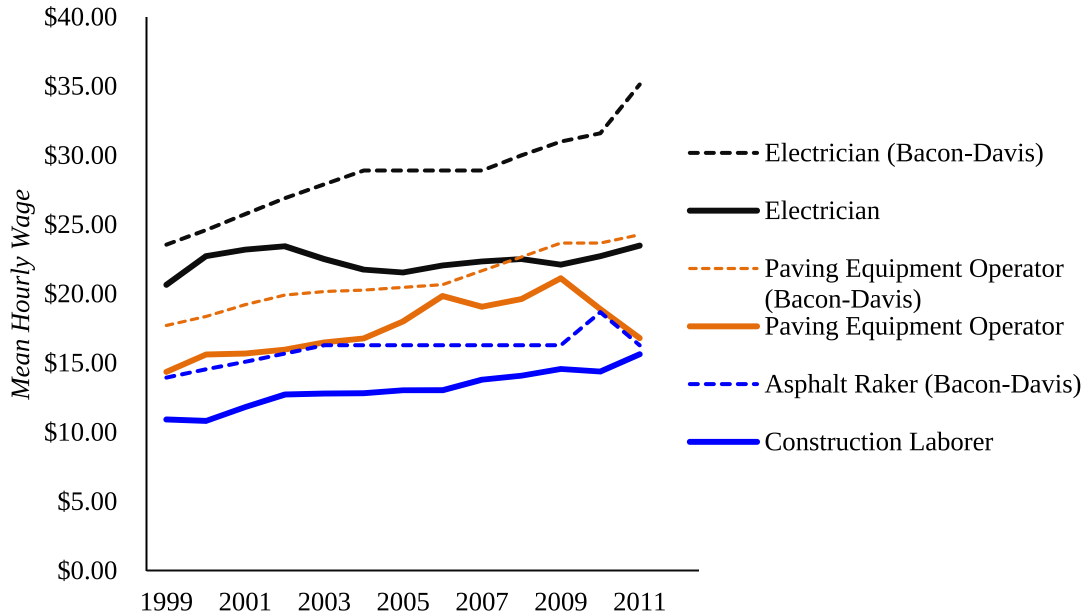
[8] US DOL form WD-10

[9] General decisions HWY-CO16 through HWY-CO24, Wage Determinations OnLine.gov, http://www.wdol.gov/Index.aspx

[10] The OES program uses U.S. Census Statistical Areas, while the Bacon-Davis Act general decisions use counties; the OES program uses the Standard Occupational Classification, whereas the Bacon-Davis Act general decisions use derivations of occupational that are defined in the Act.

Exhibit 15: Actual Wages and Prevailing Wages, Denver Area



We reject the estimates of prevailing fringe benefits that are published in Bacon-Davis general decisions as our measure of the cost of labor in favor of the wage estimates published in the OES estimates; the Bacon-Davis general decisions are generated from surveys that are smaller than the OES surveys and the data definitions, tied as they are to the original Bacon-Davis act, are archaic. The Bacon-Davis general decisions do, on the other hand, provide us with our best estimate of the costs of fringe benefits.

E. Construction Sector Input and Output Prices

The BLS estimates and reports a composite price index for all inputs into the construction industry, nationwide. The quantities used to weight the component unit prices are the averages across all types of construction that BLS reports upon: residential, non-residential, and other. BLS also reports on the producer prices of the construction industry. This index, the equivalent to the CCCI, averaged across all construction sectors and all states would be a useful statistic in the analysis of market structure in Colorado highway construction. Unfortunately, the BLS discontinued its long-standing data series for highway and street construction in 2010. The BLS has put data series for new classifications of the construction industry into place, but they cannot be compared directly with the old data in time series analyses.

Exhibit 16: Construction - All Input Prices

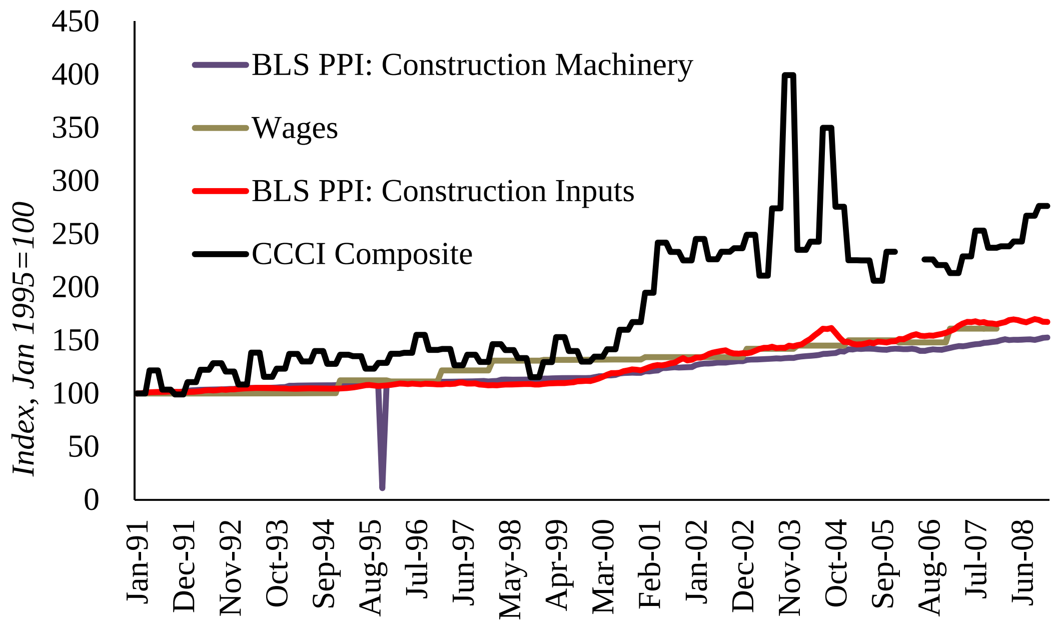


Exhibit 16 above brings together three high-level measures of the costs paid by highway contractors:

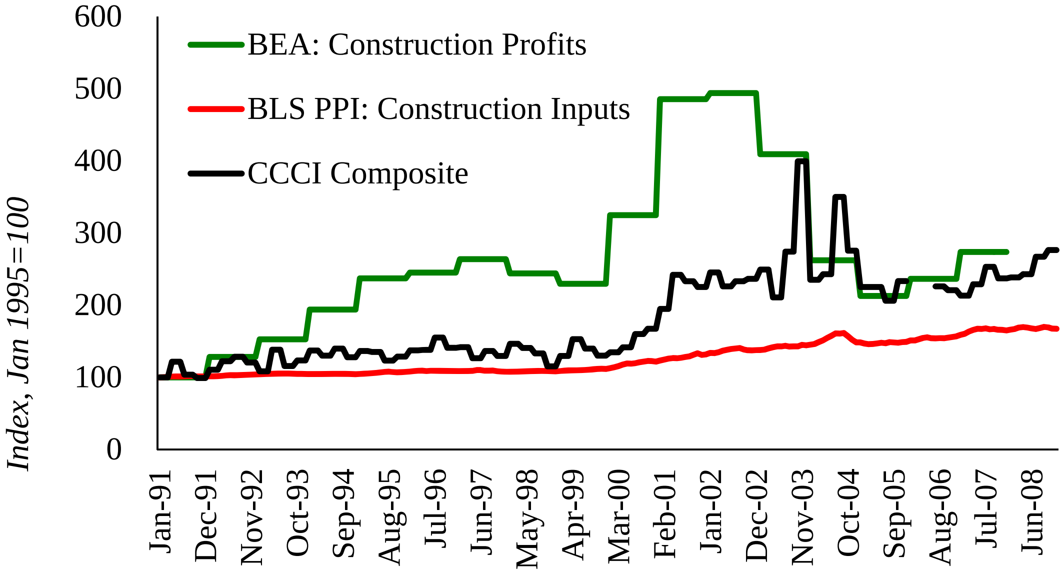
- Wages paid by contractors to their workforce (i.e., not including those wages paid the suppliers of materials to their workforces), which is a reasonable indictor of the cost of labor to the construction industry
- The PPI for the U.S. construction machinery industry (i.e., weighted average price at which that industry sold one piece of new construction equipment), which is a reasonable indicator of the cost of capital equipment to the construction industry
- The PPI for all construction inputs, including the wages and construction equipment above, as well as all commodities and intermediate products

It appears what weighted average prices that CDOT paid for construction increased in line with the costs of inputs into the U.S. construction industry until about 2004, when the indices diverge. From about 2004 to 2008, the average price of construction grew at rates significantly higher than the rates of price increases in construction industry inputs, creating a gap between them. Throughout this period, the construction industry commanded higher prices for their outputs than the costs of their inputs required. In the period 2009 to 2011, the gap ceased to widen, as the rate of increase in the costs of construction paid by CDOT fell back to equal the increases in the costs of construction inputs. In 2012, the CCCI has begun, once again, to grow at a greater rate than construction prices.

F. Costs, Profits, and Demand

The widening gap between the output prices and input prices of Colorado highway construction from 2004 to 2008 begs the question of where the money went. Exhibit 17 below shows BEA estimates of the corporate profits earned after tax by the U.S. construction industry and indicates that a significant portion of CDOT's highway construction expenditures in that period appeared in those profits.

Exhibit 17: Construction Sector Profits

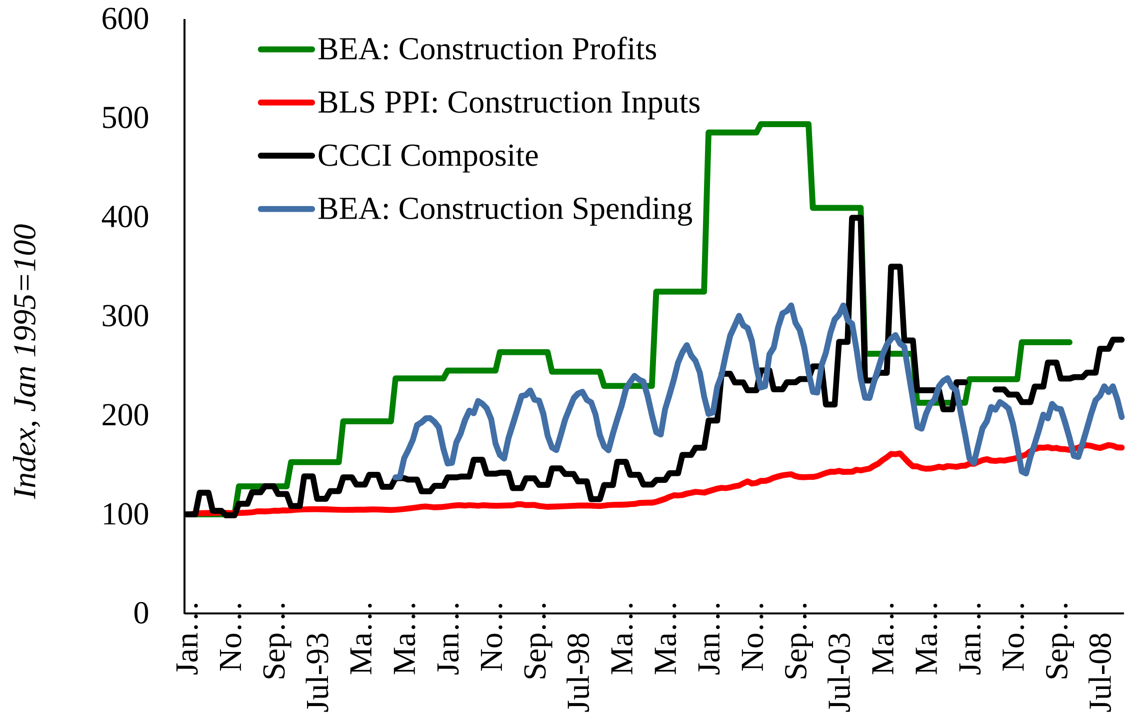


The data series in Exhibit 17 above are useful for seeing the relationships among input prices, output prices, and profits. However, they cannot form the basis of an economic hypothesis. In economics, prices are the results of economic causes: demand and supply. To form a hypothesis about the price of highway construction in Colorado, we investigate causal variables.

Classical economic theory, both price and quantity are determined by the interaction of supply and demand. Increased costs of inputs will increase the cost of supply, as we have investigated in the sections above. As the cost of supply increases, the price of construction will rise and the other sectors of the economy that use construction services will demand less of it: prices go up and the quantity of construction goes down. Changes in demand will also result in changes in price and quantity: as demand increases, prices and quantities go up; as demand decreases, prices and quantities go down.

With measures of input costs already in hand, we require a measure of demand for construction. There is no direct measure of construction demand that is readily available, so we use construction spending as a proxy for it. Construction spending is an imperfect proxy for demand since it is a product of price and quantity: price is the dependent variable on which we estimate demand's effect and quantity is demand after it has been constrained by supply and price. Imperfect as it is, however, construction spending does provide an indication of changes in demand.

Exhibit 18: Spending on Construction



In Exhibit 18 above, we add the BEA estimate of construction spending in the national economic accounts to the time series for all input prices, the CCCI, and national construction industry profits. These data are estimated by month, and in this Exhibit 18, are not seasonally adjusted. The overall trend shows that increases in construction costs and construction sector profits from 2004 to 2008 did coincide with an increase in construction spending. Seasonal construction spending in the United States is made up of all types of construction, including both public and private sectors. The annual cycles indicate that variations in construction spending from winter to summer have an effect on the CCCI.

III. Appendices

A. Price Indices

Price indices measure changes in prices, **P**, over time (i.e., from a base period ***0*** to a current period **t**), aggregate the price changes of individual items, ***i***, item **1** through item ***N***, into a single price for the aggregate of the items. For example, the consumer price index is estimated by compiling the weighted proportions of individual household expenditures into a “basket” of goods and services that represent the expenditures of a typical household.

Over a period of time, the price of the individual items, $\mathbf{p_i}$**,** in a “basket” will change and the quantities, $\mathbf{q_i}$, in the “basket” will also change. The first challenge encountered when measuring the aggregate price of a “basket” is to isolate and remove the changes in the quantities of the individual items that will cause the aggregate price to change. This is akin to a variance analysis that, in accounting, reports how changes in quantity between period ***0*** and period ***t*** and changes in price between period ***0*** and period ***t*** contributed in changes of value from period ***0*** to period ***t***.

In the following three formulae:

P	=	price index between period ***0*** and period ***t***
p_{i0}	=	price of item ***i*** in the base period ***0***
p_{it}	=	price of item ***i*** in the current period ***t***
q_{i0}	=	quantity of item ***i*** in the base period ***0***
q_{it}	=	quantity of item ***i*** in the current period ***t***

The most common price index is the Laspeyres Index, which estimates the change in value of a single item by comparing the initial price to the final price in the initial quantity, thus removing the changes in value due to changes in quantity:

$$P_{Laspeyres} = \frac{p_t q_0}{p_0 q_0} \quad \text{Equation 3}$$

Or for a basket of goods, 1 through N, the Laspeyres Index is:

$$P_{Paasche} = \frac{\sum_{1}^{N}\left(p_{it} q_{i0}\right)}{\sum_{1}^{N}\left(p_{i0} q_{i0}\right)} \quad \text{Equation 4}$$

The CCCI was calculated as a Laspeyres Index from 1987 to 2012.

The Paasche Index estimates the change in value of a single item by comparing the initial price to the final price in the final quantity:

$$P = \frac{p_t q_t}{p_0 q_t} \qquad \text{Equation 5}$$

Or for a basket of goods, 1 through N, the Paasche Index is:

$$P = \frac{\sum_{1}^{N} \left(p_{it} q_{i_t}\right)}{\sum_{1}^{N} \left(p_{i0} q_{i_t}\right)} \qquad \text{Equation 6}$$

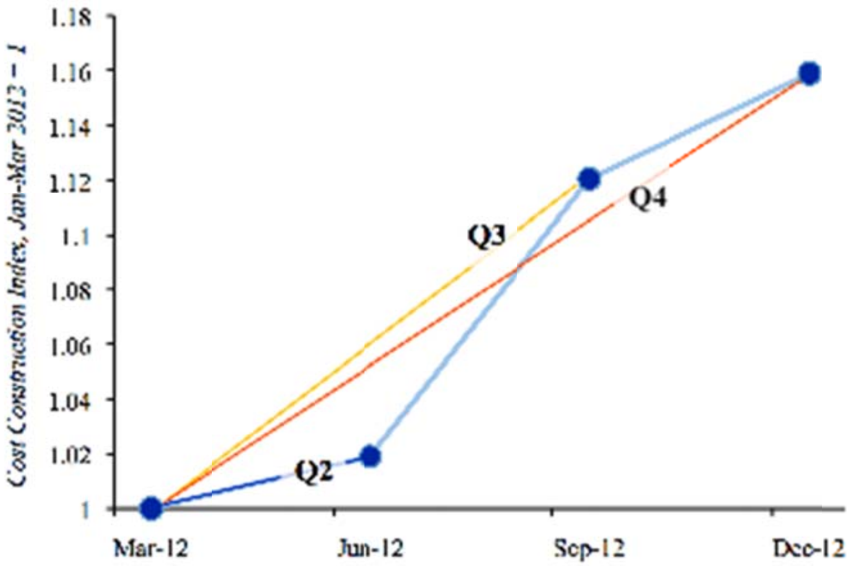
The Laspeyres and Paasche indices are asymmetrical. If the quantity of a single item changes from the beginning, ***0***, to the end, ***t***, of a period, then the Laspeyres and Paasche indices yield different values of ***P*** for the same change in prices. The simplest of the so-called superlative indices, which are symmetrical and account for prices and quantities equally across time periods is the Fisher Index. The Fisher Index is calculated by multiplying the Laspeyres and Paasche indices together and taking the square root of the result:

$$P_{Fischer} = \sqrt{P_{Laspeyres} \bullet P_{Paasche}} \qquad \text{Equation 7}$$

Blending the quantities at the beginning and the end of a period, the Fisher Index eliminates distortions in the price index, due to quantity changes from period ***0*** to period ***t***. However, it does not eliminate the effects of changes through a series of periods. Taking the CCCI for 2012, a Fisher Index, as an example:

Exhibit 19: Colorado Construction Cost in Fisher Index Form

Quarter Ending….	Mar-12	Jun-12	Sep-12	Dec-12
Cumulative Fisher Index	1	1.019	1.1204	1.159



The values reported for the CCCI in 2012 are shown in the table above and also as the blue circles in the chart above. The Fisher Index compares prices and quantities between the beginning and the end of each period, with no regard to the changes in between; the fourth quarter value of 1.159, for example, measures the change shown by the red line without taking into account the prices at the end of the second or the third quarters, and the third quarter value of 1.1204 measures the change shown by the yellow line without taking into account the prices at the end of the second quarter. To estimate those price changes from quarter to quarter in a time series, CDOT also estimates the relative index, which is the amount by which the index at the beginning of the period must be multiplied by to equal the index at the end of the period.

Exhibit 20: Colorado Construction Cost in Fisher Index Form

Quarter Ending….	*Mar-12*	*Jun-12*	*Sep-12*	*Dec-12*
Cumulative Fischer Index	1	1.019	1.1204	1.159
Relative Fischer Index	1	1.019	1.0995	1.0344

The relative index for the third quarter is $1.0995 = \frac{1.1204}{1.1019}$ and the relative index for the fourth quarter is $1.0344 = \frac{1.1590}{1.1204}$.

The relative index is the more useful Fischer Index for observing changes in prices over two or more consecutive periods.

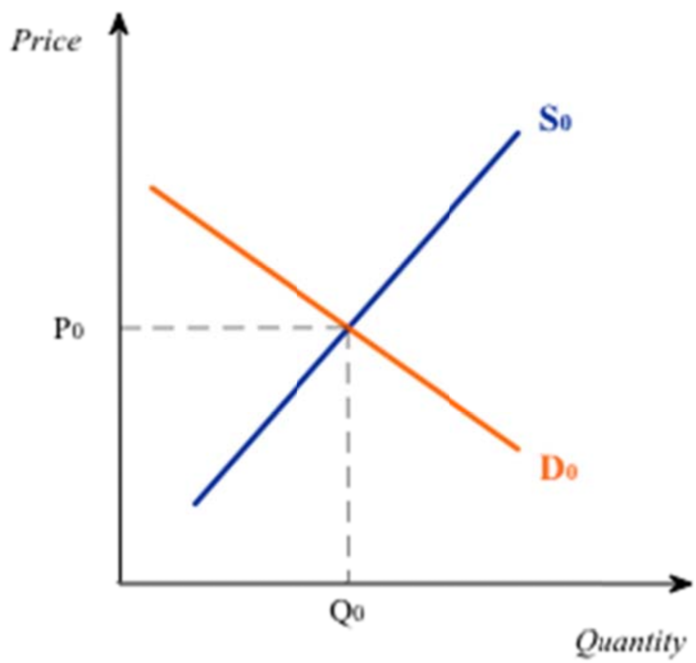
B. The Elasticity of Construction Supply with Respect to Price

Our demand-based approach to forecasting the cost of construction relies on cause and effect in a market for highway construction, in which supply and demand interact to guide the market to an equilibrium price at which the market clears. A key economic principle in our market-based approach is elasticity, the measure of the extent to which highway contractors respond to increases in highway programs by raising their prices, rather than by increasing their construction capacity. This appendix explains elasticity in terms of simple market economics, assuming that the reader has little knowledge of microeconomics.

1. Supply and Demand in the Highway Construction Market

The three exhibits below are universally used in basic microeconomics to explain how supply and demand interact to find an equilibrium price at which the amounts suppliers are willing to sell and the amounts consumers are willing to buy are equal. At that price and that quantity, the market clears and there is no buildup of unwanted inventory or back-orders.

Exhibit 21: Supply and Demand in Initial Equilibrium



The blue line is the supply curve, $\boldsymbol{S_0}$, showing the amounts of construction, ***Q***, that the construction industry will undertake at different prices for construction, ***P***. The supply curve slopes upward because the higher the price, the more work the industry will undertake. The orange line is the demand curve, D_0, showing the amounts of construction that the other industries will want the construction industry to undertake at different prices for construction. The demand curve slopes downwards because the lower the price, the more construction work other industries will want the construction industry to undertake. The market clears at the price P_0 and quantity Q_0; the department of transportation receives bids on all of the contracts in its program and prices are stable.

Exhibit 22: Increased Spending Increases Demand

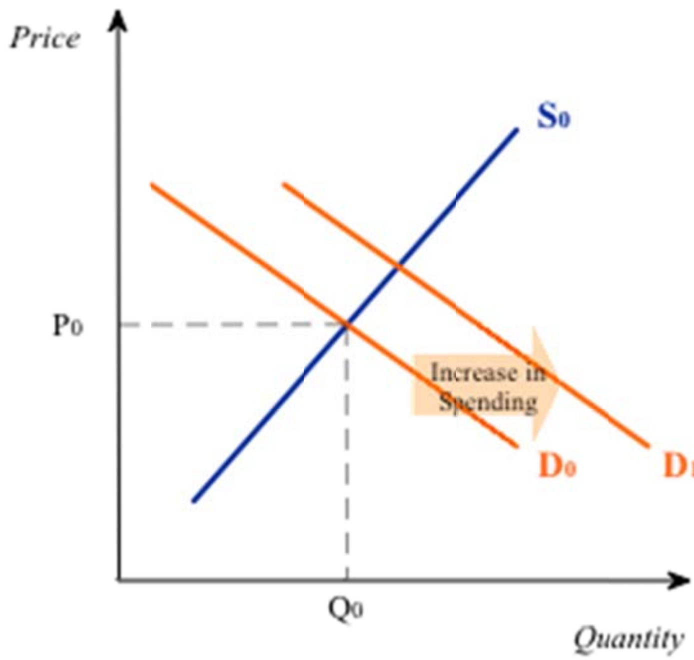
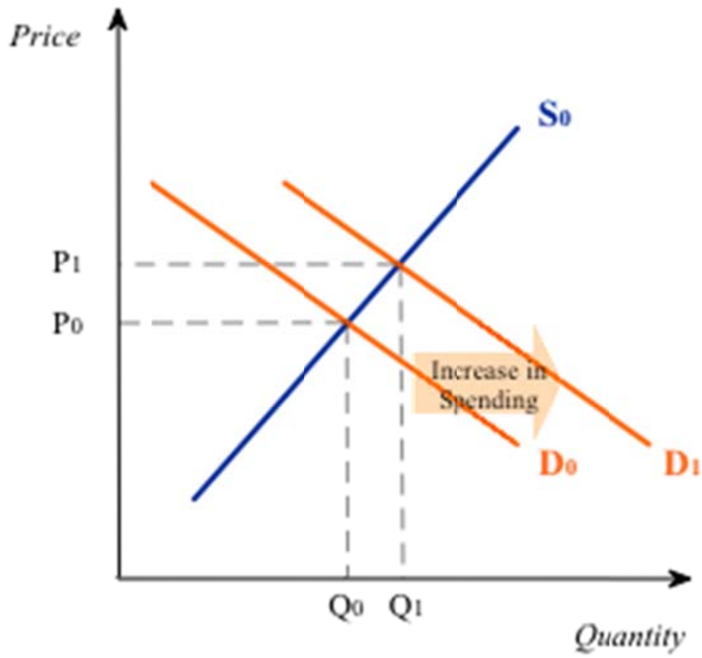


Exhibit 22 above illustrates an increase in the department of transportation's highway program. The increase in funds available shifts the demand curve to the right, from D_0 to D_1. On the new demand curve, the DOT will demand more construction capacity at any given price. At P_0, the price at which the market for highway construction was in equilibrium before the department of transportation's highway construction program increased, the department would purchase a significantly higher quantity of construction than the construction industry can afford to supply at that price. The increased funding of the highway construction program has pushed the market out of its initial equilibrium at P_0 and Q_0.

Below illustrates the market for highway construction adjusting to the DOT's increased spending on highway construction. Through a series of transactions in which too many dollars chase too few highway construction resources, the price for highway construction is bid upwards. The higher prices allow construction contractors to attract more labor, capital, and raw materials into their building and management capacity, and at those higher prices, they can undertake more work. Eventually, the market settles at a new equilibrium, P_1 and Q_1, at which more work is undertaken, higher prices are paid, and the DOT construction budget is fully obligated.

Exhibit 23: Supply and Demand in Final Equilibrium



Our principal interest is the extent to which the additional funds in the highway construction program, which pushed demand in the highway construction market from D_0 to D_1, have been absorbed by the construction industry in higher costs, rather than in providing more construction capacity. That requires a numerical comparison of the price increase, from P_0 to P_1, to the quantity increase, from Q_0 to Q_1. Engineers and economists will recognize that such a numerical comparison will be based upon the slope of the supply curve between the two points, P_0,Q_0 and P_1,Q_1:

$$m = \frac{(P_1 - P_0)}{(Q_1 - Q_0)} = \frac{\Delta P}{\Delta Q}$$

Equation 8

2. Elasticity

The economic measure for that comparison is elasticity. In the highway construction market, elasticity is the change in the amount of highway construction obligated divided by the total amount obligated that results from a given change in the price of highway construction, divided by overall price. The elasticity value η is calculated as the percent change in quantity, Q, divided by the percent change in the cost, P. Using the example illustrated in the three exhibits above:

$$\eta = \frac{\left((Q_1 - Q_0) \big/ Q_0 \right)}{\left((P_1 - P_0) \big/ P_0 \right)} = \frac{\left(\Delta Q \big/ Q \right)}{\left(\Delta P \big/ P \right)} \qquad \text{Equation 9}$$

Elasticity is based upon the inverse of the slope of the supply curve and it measures the responsiveness of quantities (e.g., the number of highway projects that can be construction) to a change in the cost of construction.[11] A steeper slope (i.e., when $0 < \eta < 1$) means that the supply curve is relatively inelastic; the capacity of the construction industry is not readily expandable and the industry will raise its prices to absorb most of the budget increase in the DOT's highway program. A shallower slope, (i.e., when $\eta > 1$) means that the supply curve is relatively elastic; the competition from new contractors or the ability of at least one established contractor to expand their capacity will result in most of the budget increase that the DOT's highway program funding additional projects.[12]

The numerical estimate of elasticity is interpreted as the ratio of percentage change in quantity to the percentage change in price. An elasticity of 0.3, for example, means that the quantity of construction will increase by 0.3 percent for each 1 percent increase in the price of construction, and an elasticity of 2 means that means that the quantity of construction will increase by 2 percent for each 1 percent increase in the price of construction. Elasticity is thus the most important measure of the changes in construction costs that will result as state DOTs increase their highway construction programs.

3. Other Estimates of the Elasticity of Supply in Construction Markets

Conceptually, estimating the elasticity of supply is simple; in practice, it is not. The quantity of construction is difficult to measure, since construction activity is most often defined in terms of budgets and value, $\boldsymbol{V=PQ}$. It is difficult to disentangle prices from published values to arrive at reliable measures of the quantities of construction that are independent of prices. Also, elasticities change over time, as construction companies acquire additional equipment and innovate new contracting and management methods in response to a sustained increase in demand.

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[11] When the value of η is negative, quantity varies inversely with cost. When costs go down, the quantity of travel goes up; this is the common relationship between transportation fees and the amount of travel. It is rare that the value of η is positive (i.e., that quantity varies directly with cost, such that increased costs result in increased amount of travel).

[12] *In extremis*, a vertical supply curve means that the supply of the good will not change, regardless of the price. An example of a good with a vertical supply curve is freehold land within an urban boundary; the market cannot produce more land in response to increased demand. A horizontal supply curve means that all changes in demand are met by increasing or decreasing the quantity supplied, with no change in the price. An example of a good with a horizontal supply curve is all national parks in remote locations. The cost of providing access to the parks, including the entrance fee, is uniform, and there is ample capacity to accommodate any level of demand for visits to these remote parks.

We reviewed the literature to find studies that had attempted to estimate the price elasticity of the supply curve in the construction industry and found none outside the field of residential construction. We suspected that this unfortunate result was due to the intractable problem of changing quantities in heavy construction contracts. Only in the residential construction sector, where the quantities of inputs and the nature of the construction is fairly uniform, can published data the reports the value of construction be manipulated to impute the price of construction. We confirmed this lack of research, and our suspected reasons for it, with three experts in the field of construction economics.[13]

We found only one study of direct relevance: an estimate of the elasticity of supply in construction machinery, commissioned by the U.S. Federal Reserve Board to estimate the extent to which the *American Recovery and Reinvestment Act* (2009) drove up the price of construction machinery.[14] This study concluded that highway construction equipment had an elasticity of about 9 during this period, largely by virtue of imports from other countries, such that the increase in the prices of highway construction equipment did not increase significantly. This study is an example of how elasticities can be estimated when the nature of the good does not change from one unit to another; units of construction equipment, like units of residential housing, are not unique.

4. Further Reading

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Mr. Graham Ive, The Bartlett School of Construction, University College London.
Dr. Karl Goran Runeson, Professor, Faculty of Design Architecture and Building, University of Technology Sydney.

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C. Unit Prices and Bid Item Quantities

This appendix describes the unit price and quantity data from which the CCCIs are estimated.

The CDOT *Construction Item Book* (June 2012) contains 5,824 items, excluding force accounts. To each of these items is assigned an eight-digit code in the format NNN-NNNNN. These codes are arranged in a hierarchy by the first three digits of the code. The highest level of the hierarchy is the section index, shown in the left-hand column of the table below. The second level of the hierarchy is the item index, grouped within the section indices. Almost all individual items are then assigned to one index on the second level.

We transcribed from the CDOT *Construction Cost Data Books* the weighted average for each quarter of the unit/quantity and the awarded bid all of construction items that appeared in those from for the years 2005 to 2008 inclusive, 2010, and 2011. We transcribed no data prior to 2005, since we understand that a different specification of items was used in those years, such the data from the two periods could not be chained together. There are no data transcribed for 2009.

Exhibit 24: Hierarchy of CDOT Construction Item Codes

Section Indices	Number of Indices in the Section	Number of Items in the Section
200 Earthworks	15	678
300 Bases	3	41
400 Pavements	10	286
500 Structures	16	351
600 Misc. Construction	29	4,149
Unassigned		319
Total	**73**	**5,824**

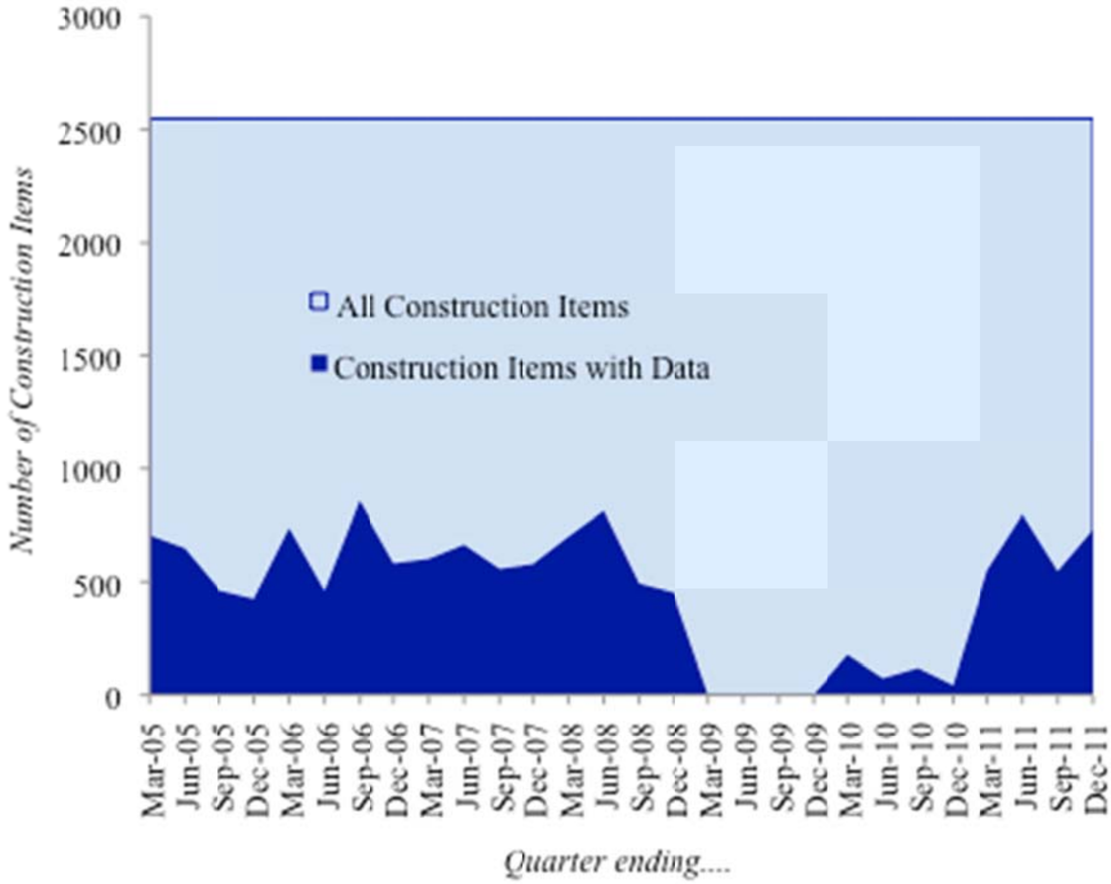
Over 5,000 individual items is an unmanageable number of items to forecast individually, so we chose groups of items and individual items to put into samples to forecast aggregated construction costs. We used four criteria to choose which items we would use as dependent variables.

1. Where the data are available
2. Where the values are a large part of total construction expenditures
3. What items are important in the engineering and construction of projects
4. What items are related to macroeconomic variables that can be forecasted

1. Where the Data Are Available

Only 2,302 of the 5,824 cost items appeared in the *Construction Cost Data Books* for the seven years under study, which implies that, in the years for which we downloaded data, 3,522 of the cost items were not included in any awarded contract. Also, these 2,302 cost items appeared in at least one quarter, but not in all quarters. On average, only 540 of the 2,302 of the items contain data in a quarter. The number of construction items that contain data vary widely around that average, as the Exhibit 25 below illustrates.

Exhibit 25: Construction Items with Data, by Quarter



One of our principal interests is to build time series of construction costs (i.e., to include construction items that were used, and thus are present in the data, for all twenty-four of the quarters in the study period 2005-2008 and 2010-2011). Unfortunately, very few of the cost items report data in all twenty-four quarters. Cost items appear, on average, in only six of the twenty-four quarters.

2. Where the Values Are Concentrated

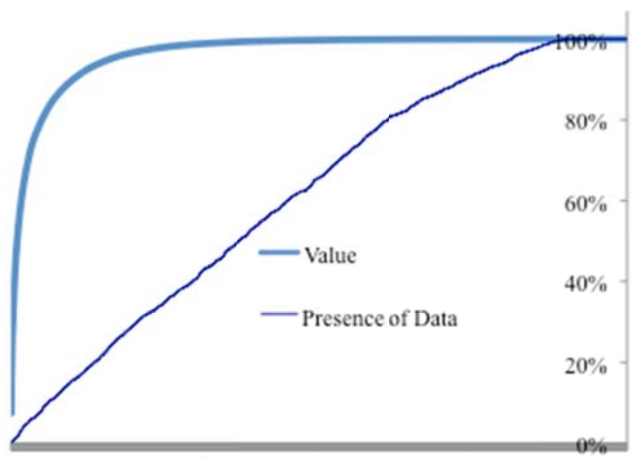
We hoped to find some correlation between the presence of data in the twenty-four quarters and the importance of construction items; that those items for which there were data in relatively few quarters were relatively small items in terms of their value, or that those items for which there were data in relatively few quarters were items that had a smaller number of contracts awarded. Unfortunately, as Exhibit 26 below illustrates, neither of these hypotheses are true. There is a weak correlation between the number of quarters in which data appear for a construction item and the number of bids that were awarded for that item. There is no correlation between either of those measures of data incidence and the total values awarded under that item.

Exhibit 26: Pearson Correlation Coefficients (r_{XY}) in Quarterly Data

	Quarters with Data for the Item	Number of Contracts, Including the Item	Sum of Amounts
Quarters with Data for the Item	1	0.26	0.04
Number of Contracts, Including the Item		1	0.05
Sum of Amounts Awarded for the Item			1

We found that the value of the awarded contracts is moderately concentrated, with 80 percent of the total value of the awards spread across 240 of the 2,302 construction items. Those same 240 items, however, account only for 12 percent of data present in the quarterly construction items. Even in those items in which it is most heavily concentrated, 80 percent of the data is spread across 2,005 of the 2,302 construction items. These concentrations, illustrated more generally in the Lorenz curves below, lead us to conclude that there is no small subset of construction items within the full set of 2,302 items that represent most of the contract values and most of the available data.

Exhibit 27: Concentrations of Value and Data Presence in Quarterly Data



3. What Items Appear Important

We describe in this section how we develop two different sets of the construction item data for testing against the independent variables, both based on the engineering characteristics of the items.

The simple list of the "Top 40" items by value, appended to these notes, demonstrates the expected preponderance of asphalt cement and concrete materials. Some labor-intensive items also appear in the "Top 40" by value: traffic control and construction surveying, the latter being the only of the “Top 40” by value items to also appear on the “Top 40” items, when listed by the availability of data.

The seventy-three indices that CDOT has developed to aggregate construction items by engineering differences would be an excellent means of aggregating the data, but for the differences in the units among the individual items. The table below illustrates the obstacle.

Exhibit 28: Sample of Items in Index 210 ("Reset Structures")

Item Number	Item	Units	Quarters with Data (out of 24 Quarters)	Sum of Items	Sum of Values
210-00090	Reset Delineator	each	1	2	$61,746
210-00300	Reset Brick Pavers	yd^2	0	0	$19,523
210-00410	Modify Bridge Expansion Device	each	4	789	$11,330
210-00415	Repair Rail Expansion Joint	each	1	8,405	$0
210-00425	Reset Bridge Railing	ft	4	216	$32,070
210-00427	Reset Pipe Hand railing	ft	8	23	$235,340

The values of these six items and the other eighty-six items in the “Reset Structures” index could be added together, but their quantities cannot be, as they are specified in different units. If different units were added together, the changes in value due to changes in volume could not be distinguished from changes in value, due to changes in price, and the latter is the relationship that we are trying to isolate.

We found numerous instances among the construction items in which the only difference between items was in their units of measurement, as can be seen in the example below.

Exhibit 29: Sample of Items in Index 304 ("Aggregate Base Course")

Item Number	Item	Units	Quarters with Data (out of 24 Quarters)	Sum of Items	Sum of Values
304-01000	Aggregate Base Course (Class 1)	ton	2	22,189	$4,223,972
304-01005	Aggregate Base Course (Class 1)	yd^3	9	131,699	$89,562
304-02000	Aggregate Base Course (Class 2)	ton	3	7,327	$3,230,826
304-02005	Aggregate Base Course (Class 2)	yd^3	3	4,427	$649,161
304-03000	Aggregate Base Course (Class 3)	ton	4	13,984	$2,026,430
304-03005	Aggregate Base Course (Class 3)	yd^3	1	37,225	$257,296

Being able to add together only like units, we had to find another means to reduce the 2,302 individual items in the data into a smaller number of dependent variables.

a. Simple Reduction

We built one sample of construction items by choosing some items and not others, such that the sample contained no aggregations of items.

We manually reviewed each of the 2,302 items that held data for at least one quarter in the seven years under study and selected 254 of them with that; include at least one item from each of the seventy-three CDOT index groups, include as much of the total value as possible, and include as many quarters as possible. The 254 items that we manually selected cover 48 percent of the total value of construction, include 21 percent of the all of the quarters in the study period, and include 39 percent of all individual items recorded in all contracts.

We matched these 254 items to the appended list of the “Top 40” items by value and found that twenty-two of these items were among the manually selected items. The other eighteen items consisted of five grades of structural concrete, two grades of Portland cement concrete pavement, ten grades of bituminous pavement, and one type of guardrail. Since all of these items were represented in the manually selected list by similar grades of those items, we did not add them to the sample.

We also matched the manually selected items to the “Top 40” items by presence in the data, finding that the 254 items excluded fourteen items from that “Top

40" list. We added five of those items to the manually selected list, such that it now covers 51 percent of the total value of construction, includes 22 percent of the all of the quarters in the study period, and includes 40 percent of all individual items recorded in all contracts.

b. Aggregation of Similar Grades

Within each of the seventy-three CDOT indices, we grouped all individual items by their units of measure, of which there are sixteen in the data.

Exhibit 30: Distribution of Construction Items Across the Units of Measure

Unit of Measure	Number of Items
Linear Foot	739
Mile	1
Million board feet	2
Acre	18
Square Foot	117
Square Yard	196
Cubic Foot	8
Cubic Yard	115
Gallon	22
Hour	49
Day	14
Pound	14
Ton	70
Million Kip Feet	5
Each	812
Lump Sum	120
Total	**2302**

Across a possible matrix of seventy-three indices and sixteen units of measure, (i.e., 1168 elements), we assigned all of the construction items in the data into one of 221 elements. This provides us an aggregation of the data into 211 dependent variables that include virtually 100 percent of the data, with the risk that some changes in the value of these groups is caused not by price changes, but by shifts in the makeup of the groups.

4. What Items Relate to Macroeconomic Variables

We establish a third set of the construction item data for testing against the independent variables by aggregating, as much as is practical, the 2,302 items in data by their inputs, be they labor, equipment, or different materials. By manual and approximate review, we defined the following input categories and distributed all of the data items across them.

Exhibit 31: Distribution of Construction Items by Their Inputs

Input Category	Number of Items
Adjustment and modification	86
Aggregates	31
Asphalt	106
Chemicals	6
Concrete in place	106
Concrete pavement	46
Concrete pipe	69
Concrete pipe, installed	16
Concrete precast	169
Concrete structural	30
Electrical component	165
Equipment	30
Excavation, removal, and clearing	142
Facilities	32
Fence	104
Fill, placement, shaping, and lining	105
Labor	47
Labor and equipment	90
Marking	111
Organic material	61
Piping components	63
Plastic material	67
Plastic pipe	36
Professional services	35
Railing	79
Riprap	26
Signs and poles	166
Steel	26
Steel pipe	188
Steel structure	71
Systems	177
Wood products	4
Grand Total	**2490**

The number of items total to 2,490 in this distribution because they contain 188 construction items that include a number of items but at a unit price of $0.

D. Fuel and Asphalt Cement Cost Adjustments

Since 2007, CDOT has shared with its construction contractors some of the risk of changes in the price of asphalt after construction contracts are let. As the price of crude oil varies throughout the duration of a construction contract, the contractors are permitted to claim an adjustment to the amounts they are paid for they deliver. The adjustment mechanism is stipulated by CDOT and is the same all contracts: the price for crude oil[15] in the month before the contract is let is taken as the base price for adjustments during the contract. If the price of crude oil during a month of the contract in which asphalt is delivered is more than 105 percent of the base price, then the contractors are entitled to adjust their invoices for the difference in the two prices. Once the contract is awarded, the unit price declared by the winning contractor becomes the base price with a corresponding base price for crude oil.

To form an initial indication of the magnitude of fuel cost adjustments, we analyzed a set of 243 contracts for federal aid projects, on which the final "estimate" payment was made between August 2007 and September 2010. These data are the sum of the fuel adjustments paid through force account 700-70016 in all estimates in each contract. The sum of fuel adjustments across all 243 contracts is $3.6 million, about 0.4 percent of the total bid value of these contracts ($720 million). Some of these adjustments are negative and the absolute value of the fuel adjustments is $3.6 million, 0.5 percent of the total value of the contracts. We had no access to the adjustment in each estimate, only the sum of adjustments for each contract. With such access, we would expect to find that the individual adjustments that make up the sums for each contract contain positive and negative values and that the absolute value of these adjustments would be greater than 0.5 percent of the total contract value.

Fuel cost adjustments are separate from and smaller than the asphalt cost adjustments that are in force account 700-70019.

E. “Top 40” Construction Items by Value

Item Number	Item	Quarters with Data (out of 35 Quarters)	Sum of Values	Cumulative % Sum of Values
626-00000	Mobilization	2	$120,002,144	3%
601-03040	Concrete Class D (Bridge)	1	$37,241,854	3%
403-34701	Hot Bituminous Pavement (Grading SX) (75)	16	$36,324,678	5%

[15] The price declared by Cenovus Energy for Western Canadian Select grade delivered at Hardisty, Alberta. Hardisty is the nexus of several continental pipelines, including the Keystone Pipeline, and is one of the points of delivery for sales of crude oil by North American producers to North American refineries.

Item Number	Item	Quarters with Data (out of 35 Quarters)	Sum of Values	Cumulative % Sum of Values
403-33841	Hot Bituminous Pavement (Grading S) (100) (PG 64-22)	1	$32,088,963	7%
403-34871	Hot Bituminous Pavement (Grading SX) (100) (PG 76-28)	5	$27,607,220	9%
630-00012	Traffic Control Management	8	$26,733,611	13%
403-34721	Hot Bituminous Pavement (Grading SX) (75) (PG 58-28)	9	$26,427,436	14%
630-00000	Flagging	19	$25,281,169	16%
403-33741	Hot Bituminous Pavement (Grading S) (75) (PG 64-22)	1	$24,539,020	18%
203-00010	Unclassified Excavation (Complete In Place)	5	$21,423,190	19%
403-09210	Stone Matrix Asphalt	1	$21,340,184	21%
403-34841	Hot Bituminous Pavement (Grading SX) (100) (PG 64-22)	18	$21,279,095	22%
203-00060	Embankment Material (Complete In Place)	18	$19,685,268	23%
403-09221	Stone Matrix Asphalt (Fibers)(Asphalt)	6	$18,439,340	25%
412-01200	Concrete Pavement (12 Inch)	3	$17,399,975	26%
411-03355	Asphalt Cement Performance Grade (PG 58-34)	2	$16,923,422	27%
627-00005	Epoxy Pavement Marking	20	$14,570,603	28%
412-01300	Concrete Pavement (13 Inch)	1	$14,543,759	29%
403-33751	Hot Bituminous Pavement (Grading S) (75) (PG 64-28)	18	$14,267,390	30%
630-80370	Concrete Barrier (Temporary)	3	$14,144,743	31%
403-33851	Hot Bituminous Pavement (Grading S) (100) (PG 64-28)	3	$14,128,361	32%
411-03352	Asphalt Cement Performance Grade (PG 58-28)	0	$13,716,683	33%

Item Number	Item	Quarters with Data (out of 35 Quarters)	Sum of Values	Cumulative % Sum of Values
625-00000	Construction Surveying	24	$12,292,162	34%
403-00720	Hot Bituminous Pavement (Patching) (Asphalt)	5	$12,206,874	34%
403-34851	Hot Bituminous Pavement (Grading SX) (100) (PG 64-28)	1	$11,951,890	35%
403-34741	Hot Bituminous Pavement (Grading SX) (75) (PG 64-22)	11	$11,949,056	36%
621-00450	Detour Pavement	0	$11,860,489	37%
304-06000	Aggregate Base Course (Class 6)	7	$11,725,803	38%
412-01250	Concrete Pavement (12-1/2 Inch)	3	$11,245,586	38%
403-34751	Hot Bituminous Pavement (Grading SX) (75) (PG 64-28)	3	$10,713,369	39%
206-00100	Structure Backfill (Class 1)	20	$9,643,920	41%
304-06007	Aggregate Base Course (Class 6)	15	$9,119,968	41%
403-34801	Hot Bituminous Pavement (Grading SX) (100)	11	$8,822,136	42%
203-00062	Embankment Material (Complete In Place) (Special)	3	$8,797,114	42%
606-00301	Guardrail Type 3 (6-3 Post Spacing)	9	$8,795,386	43%
601-05045	Concrete Class S40	1	$8,591,534	43%
412-00000	Furnish Concrete Pavement	1	$8,439,274	44%
206-00360	Mechanical Reinforcement of Soil	12	$8,073,316	45%
601-03050	Concrete Class D (Wall)	4	$7,683,822	45%
202-00400	Removal of Bridge	1	$7,565,154	46%

F. "Top 40" Construction Items by Presence in Quarterly Data

Item Number	Item	Quarters with Data (out of 35 Quarters)	Sum of Values	Cumulative % of Quarters with Data
625-00000	Construction Surveying	24	$12,292,162	0%
630-80355	Portable Message Sign Panel	24	$5,464,266	0%
630-00007	Traffic Control Inspection	24	$3,086,131	0%
630-00003	Uniformed Traffic Control	24	$2,540,687	1%
630-80376	Guardrail Type 7 (Temporary)	24	$1,486,027	1%
208-00040	Check Dam	24	$286,553	1%
630-80337	Barricade (Type 3 M-C) (Temporary)	24	$73,231	1%
630-80357	Advance Warning Flashing or Sequencing Arrow Panel (B)	24	$54,375	1%
630-80338	Barricade (Type 3 M-D) (Temporary)	24	$46,725	2%
629-01065	Survey Monument (Type 5S)	24	$1,370	2%
613-01200	2 Inch Electrical Conduit (Plastic)	23	$4,407,389	2%
630-80359	Portable Message Sign Panel	23	$1,364,132	2%
202-00246	Removal of Asphalt Mat (Planning) (Special)	23	$1,083,121	3%
630-80341	Construction Traffic Sign (Panel Size A)	23	$1,051,899	3%
614-01585	Steel Sign Support (2-1/2 Inch Round Sch 80) (Post)	23	$407,518	3%
614-01582	Steel Sign Support (2-1/2 Inch Round) (Post and Slipbase)	23	$256,022	3%
202-00805	Removal of Overhead Sign Structure	23	$205,019	3%
627-00002	Thermoplastic Pavement Marking	23	$134,876	4%
203-01140	Rolling	23	$126,509	4%
627-30331	Preformed Plastic Pavement Marking (Xwalk - Stop Line)	23	$106,401	4%

Item Number	Item	Quarters with Data (out of 35 Quarters)	Sum of Values	Cumulative % of Quarters with Data
613-01100	1 Inch Electrical Conduit (Plastic)	23	$87,838	4%
614-01578	Steel Sign Support (2-1/2 Inch Round NP-40)(Slipbase)	23	$71,556	4%
208-00110	Sediment Removal and Disposal	23	$68,382	4%
213-00000	Mulching	23	$63,934	5%
202-00815	Removal of Sign (Special)	23	$54,282	5%
310-00612	Full Depth Reclamation of Hot Mix Asphalt Pavement	23	$39,705	5%
213-00011	Mulching (Hydraulic)	23	$33,526	5%
626-00005	Mobilization	23	$26,000	5%
211-05003	Crack Preparation (Type 3)	23	$22,500	6%
613-81900	Mobile Light Tower	23	$16,000	6%
630-80352	Vertical Panel (Special)	23	$7,225	6%
203-01592	Front End Loader (Special)	23	$3,360	6%
411-10251	Emulsified Asphalt (CSS-1)	23	$2,516	6%
620-00012	Field Laboratory (Class 2)	22	$4,773,125	7%
630-85006	Impact Attenuator (Sand Filled Plastic Barrel) (Temporary)	22	$374,798	7%
630-80366	Portable Traffic Speed Monitor (State Purchased)	22	$80,000	7%
630-80356	Advance Warning Flashing or Sequencing Arrow Panel (A)	22	$67,390	7%
627-00004	Epoxy Pavement Marking	22	$48,616	7%
203-01591	Front End Loader (Crawler)	22	$26,824	8%

G. CDOT's Construction Item Indices

		Number of Indices in the Section	Number of Items in the Index
200	**Earthwork**	**15**	**678**
201	Clearing and Grubbing		4
202	Removal of Structures and Obstructions		176
203	Excavation and Embankment		70
206	Excavation and Embankment		36
207	Topsoil		6
208	Erosion Control		35
209	Watering		5
210	Reset Structures		149
212	Seeding, Fertilizer, and Sodding		21
213	Mulching		33
214	Planting		83
215	Transplanting		10
216	Soil Retention Blanket		32
217	Herbicide		5
250	Environmental Health and Safety		13
300	**Bases**	**3**	**41**
304	Aggregate Base Course		30
306	Reconditioning		2
307	Lime Treated Sub-grade		9
400	**Pavements**	**10**	**286**
401	Plant Mix Pavements—General		0
403	Hot Bituminous Pavement		91
405	Heating and Scarifying Treatment		6
406	Cold Bituminous Pavement		4
407	Prime Coat, Tack Coat, and Rejuvenating Agent		2
408	Joint and Crack Sealant		4
409	Seal Coat		27
411	Bituminous Materials		35
412	Portland Cement Concrete Pavement		98

		Number of Indices in the Section	Number of Items in the Index
420	Geo-textiles		19
500	**Structures**	**16**	**351**
501	Steel Sheet Piling		4
502	Piling		30
503	Drilled Caissons		30
504	Cribbing/Retaining Walls and MSE Walls		69
506	Riprap		43
506	Riprap (Gabions) and Slope Mattress		43
507	Slope and Ditch Paving		14
508	Timber Structures		5
509	Steel Structures		24
510	Structural Plates Structures		20
512	Bearing Device		9
514	Pedestrian and Bikeway Railing		18
515	Waterproofing Membrane		10
516	Damp-proofing		1
517	Water-proofing		3
518	Water Stops and Expansion Joints		28
600	**Miscellaneous Construction**	**29**	**4149**
601	Structural Concrete		80
602	Reinforcing Steel		9
603	Culverts and Sewers		386
604	Manholes, Inlets, and Meter Vaults		183
605	Subsurface Drains		29
606	Guardrail and Bridge Rail		88
607	Fences and Sound Barrier		201
608	Sidewalks and Bikeways		32
609	Curb and Gutter		61
610	Median Cover Material		13
611	Cattle Guards		30
612	Delineators and Reflectors		48

		Number of Indices in the Section	Number of Items in the Index
613	Lighting		342
614	Traffic Control Devices		494
615	Water Control Devices		117
616	Siphons		69
617	Culvert Pipes		0
618	Pre-stressed Concrete Structures		59
619	Water Lines		230
620	Field Facilities		14
621	Detour		17
622	Rest Areas and Buildings		128
623	Irrigation System		165
624	Corrosion Resistant Culverts		1,189
625	Construction Surveying		3
626	Mobilization		7
627	Pavement Marking		55
629	Survey Monumentation		15
630	Construction Zone Traffic Control		85
	Grand Total	**73**	**5,505**

319 unclassified items are excluded from this list

H. Bureau of Labor Statistics Metropolitan Areas in Colorado

14500	Boulder
17820	Colorado Springs
19740	Denver-Aurora
22660	Fort Collins-Loveland
24300	Grand Junction
24540	Greeley
39380	Pueblo

I. Bureau of Labor Statistics Non-Metropolitan Areas in Colorado

- East and South Colorado nonmetropolitan area
- West Colorado nonmetropolitan area

- North-Central Colorado nonmetropolitan area
- Central Colorado nonmetropolitan area

J. BLS SOCs Relevant to Highway Construction

47-0000	Construction and Extraction Occupations
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers
47-2021	Brickmasons and Blockmasons
47-2031	Carpenters
47-2051	Cement Masons and Concrete Finishers
47-2061	Construction Laborers
47-2071	Paving, Surfacing, and Tamping Equipment Operators
47-2073	Operating Engineers and Other Construction Equipment Operators
47-2111	Electricians
47-2141	Painters, Construction, and Maintenance
47-2151	Pipelayers
47-2221	Structural Iron and Steel Workers
47-3012	Helpers—Carpenters
47-3013	Helpers—Electricians
47-3014	Helpers—Painters, Paperhangers, Plasterers, and Stucco Masons
47-3019	Helpers, Construction Trades, All Other
47-4041	Hazardous Materials Removal Workers
47-4799	Construction and Related Workers, All Other*
47-5021	Earth Drillers, Except Oil and Gas
47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters