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MACRO MODELS OF UK CONSTRUCTION CONTRACT PRICES

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Macro models of UK construction contract prices

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This paper describes the derivation of macro construction contract price models that are based on the economic theory of demand and supply using OLS multiple regression analysis.

A structural equation model is presented which offers a structural explanation of the movements in the construction tender price index. Leading indicators of contract prices (in real terms) produced by the structural equations were unemployment level, real interest rate, manufacturing profitability, number of registered construction firms, building cost index, construction productivity and construction work stoppages. The equation produced an adjusted R^2 *of 0.97 for deflated data with minimal serial autocorrelation.*

A predictive reduced-form model is also developed that utilises simultaneous equation models comprising construction demand, supply and equilibrium models.

Keywords: Construction contract price; statistical models; construction demand; construction supply

Macro models of UK construction prices

Introduction

The construction industry is regarded as being highly competitive (eg., Runeson and Bennett [19]). According to the Bank of England, there are three different concepts of competitiveness: price competitiveness, relative cost competitiveness and relative profitability (Bank of England [5]). Though the three concepts of competitiveness are somewhat interwoven, price competitiveness is more relevant to the construction industry because of its commercial activities. Price competitiveness is achieved through the process of tendering or bidding, the degree of competitiveness being predominantly determined by the market.

Skitmore [23] described the construction market in terms of the demand and supply of construction works, and Gaver and Zimmerman [9] assessed price competitiveness and market conditions in terms of building activity, construction time, the number of competitors and the amount of cement shipped into a district. Neufville *et al* [16], on the other hand, found a link between price competitiveness and economic conditions. Runeson and Bennett [19] used construction market conditions and consequently price competitiveness in regression models in terms of unemployment, building approvals and value added. Earlier work by Runeson and Bennett [19] and McCaffer *et al* [14] examined and quantified the degree of price competitiveness of firms from both the demand and supply side.

The principle of price competitiveness supposes that a firm's product in terms of price, design, quality and other attributes matches those of other rivals. It also assumes that suppliers have freedom price setting and satisfy whatever demand is generated at that price. This situation is well established in the manufacturing sector and features in most manufacturing price equations (Eckstein and Fromm [8]; Ripley and Segal [18]).

In the construction sector, apart from some theoretical work undertaken by Skitmore [23], price competitiveness has been treated in relation to market conditions either from the demand or supply side. Little or no clear interaction between construction supply and demand has been identified. It seems difficult to measure and foresee the interaction of construction supply and demand.

Established economic theory holds that both demand and supply influence equilibrium price and quantity - construction supply depends to some extent on construction demand (Butler [7]; Anon [4]), and together the two affect price. It can be said that an increase in construction demand cannot be satisfied without an increase in production, otherwise an increase in construction price will result, except perhaps when there is idle capacity in the construction industry. The consequence of an increase in construction prices is a reduction in construction demand. It is clear, therefore that estimates of construction price based on only one of these construction activities (demand or supply) is most likely to be biased.

This paper describes the development of construction price models that depart from earlier work, in considering the price responsiveness of both construction demand and supply by adapting two methods: a single structural equation which includes construction demand and supply variables; and a simultaneous supply/demand estimation technique. The simultaneous equation technique is useful for separating demand and supply functions and provides consistent estimates of structural coefficients (Heathfield [10]). These two approaches have different uses in econometric analysis. Simultaneous equation techniques enable reduced form equations for construction price to be derived. Reduced-form equations have better predictive and control performance than the single structural equations, but with worse structural analysis performance

(Zellner and Palm [30]). Since the investigation reported in this work was concerned with both the structural analysis **and** prediction of construction prices, it becomes necessary that both these forms of equations are derived.

Theoretical Basis for Construction Price Models

Economic theory concerning the demand and supply of goods and services, provides the theoretical basis for the construction price models described in this paper.

Demand relates to the quantity of goods and services buyers (clients) wish to purchase (commission) at each conceivable price. Supply is the quantity of a good or services sellers (contractors) wish to sell (produce) at a conceivable price. A market is set of arrangements (tendering process) by which buyers (clients) and sellers (contractors) are in contract to exchange goods or services (construction service).

Holding other factors constant, the relationship between price and demand is negative, while the relationship between price and supply is positive. Thus, the demand curves slope downward and the supply curves slopes upward for most goods and services.

Neo-classical economic theory provides that market equilibrium is maintained at the intersection of the demand and supply curves. At equilibrium price, the quantity demanded is equal to the quantity supplied for a price. At any other price, the quantity traded is the smaller of the quantity demanded and the quantity supplied.

The price determination mechanism implies that there will be excess supply at all prices above the equilibrium price, and sellers are bound to react to unsold stock by cutting prices until equilibrium price at which excess supply is eliminated. Similarly, prices below the equilibrium lead to excess demand which, if not matched with instantaneous supply will tend to raise prices. This bidding up of prices should gradually eliminate excess demand until the equilibrium point is reached. It is clear therefore that, at market equilibrium, buyers and sellers can trade as much as they wish at the equilibrium price providing there is no incentive for any further price changes.

A change in any of the factors determining the demand/supply of goods and services should lead to a shift in the demand/supply curve and consequently the equilibrium point. Simultaneous shifts in the demand and supply curves produce more complex price adjustment mechanism. In this case, the equilibrium price and quantity depend on the combined effects of both shifts.

Implications of Economic Theory for Construction Price Models

Does neo-classical economic theory of price determination have any application in construction price determination? The construction industry lacks relevant literature to give a straightforward answer to this question. The known activities of the industry however points to the possible relevance of economic theory in construction price determination.

Apart from speculative or package deal work, most construction is procured by client organisations through contract auctions in which interested constructors are required to tender their prices in the form of sealed bids. At the micro level, the construction pricers respond to the aggregate demand and supply for construction as a construction firm's workload is highly correlated with general construction demand. Conversely, the price at which firms bid depends on current and the expected workloads. If clients increase construction investment in times of low price, the construction industry will tend to respond to this excess demand by increasing the bidding price. Higher construction prices encourage firms to increase production to improve profitability. Idle capacities in firms are utilised, additional organisational structures are created, and resources are expanded to buffer up production. That most construction firms have tendencies to increase supply in times of higher construction price has implications at the macro level. At the macro level, excess supply capability is created over time. The construction firms respond to excess supply by reducing prices as production capacity becomes more than the available construction demand.

This illustration shows that the construction industry contract price determination resembles the classical economic theory of price. However, the relationship between the construction demand, supply and price are subject to time lag constraints.

Causal relationships: construction demand, supply and price

The relationships between demand, supply, price and market is established in neo-classical economic theory. Free market conditions allow prices to be determined purely by the forces of supply and demand.

Construction contract prices, being determined mainly by auction, qualify the industry's commercial activity as a free market, as there are little or no barriers to entry (Hillebrandt [11]). The industry has low fixed assets and positive capital flow (Hillebrandt [11]), hence, what could constitute a barrier to entry into the industry is the ability to bid and win contracts. Similarly, although the frequent use of selective bidding for contracts in the UK restricts the number of potential participants, contractors not bidding competitively always face the risk of not being selected to tender bids in future contract auctions. The operation of a free market in the industry makes construction price highly sensitive to the forces of construction demand and supply. Construction supply and demand influence construction price and *vice versa*. Figure 1 illustrates the causal relationships between construction demand, supply and price (Skitmore and Akintoye [25]; Akintoye and Skitmore [2]).

This principle of price determination is not peculiar to construction alone. The notions that underlie the model are consistent with supply and demand concepts adopted as a basis for modelling production inventory problem for instance (Sethi and Thompson [22]). Sethi and Thompson describe, heuristically, cause-and-effect models in the field of finance, marketing, maintenance and replacement, and production inventory systems using the notions of supply and demand concepts.

The Study

This work is based on macro-economic time series data (described in Appendix 1). The raw data are derived from three major sources: (1) Economic Trends; Employment Gazette; and Housing and Construction Statistics, all published by Central Statistical Office; (2) Building Cost Information Service Quarterly Bulletin; and (3) Datastream International Ltd On-Line.

The study was conducted in two parts. Part one produced a single structural equation that offered the structural explanation of the movements in construction price level in relation to some explanatory variables. Part two produced a reduced-form model that utilised simultaneous equations comprising construction demand, supply and equilibrium equations.

Part one: single structural equation

Analysis

The analysis adopted was via the multiple regression program devised by Akintoye and Skitmore [1]). The structural equation employed explanatory variables comprising the determinants of construction demand and (*cf*. Akintoye [3]) and supply (*cf*. Skitmore and Akintoye [25]). Using this method each of the determinants is given equal opportunity in the construction price equations. The intention here is that any explanatory variable that produces an insignificant coefficient probably due to auto-correlation with another variable could be dropped and the equation re-estimated.

Because of the extensive computing time necessary for the full model, the lead relationships of the independent variables in relation to construction price were estimated first by univariate analysis prior to a full multiple regression analysis.

The univariate analysis shows the probabilities of correlations between construction price and some listed indicators. This produces an initial impression of possible lead relationships between these construction demand and supply determinants and construction price. The probabilities give the impression that the relevant variable could be excluded from the construction price prediction equation. Low probability implies strong marginal prediction power and *vice versa*. Variables with strong predictive power are taken as having not more than a probability value of 0.05, which means that there is 5 chances out of 100 (5% chance) that the particular lead of a listed variable does not belong in that prediction equation. Table 1 shows the significant lead relationships between construction price and the determinants of construction demand and supply using the univariate analysis.

From this Table it can be seen that the leads for Y^d, C^p, and P^r are consistently 0, 0 and 2 respectively. However, the leads in respect of M^p, U^e, F^r, S^T, and r are rather inconsistent. This information was incorporated into the multiple regression program by fixing Y^d, C^p, and P^r at leads of 0, 0 and 2 respectively while allowing M^p, U^e, F^t, S^T, and r to have an integer range of 0 to 8 possible lead periods. The program then computes all possible permutations of leads to find the least squares fit.

This method of analysis is not unusual in economic modelling. Burridge *et al* [6], for instance, suggest that it is commonplace for economic theory to specify economic relationships with the precise quantification of the lag distributions being best left to the data.

A structural form of equation of construction price was developed using the quarterly data from the first quarter 1974 to the fourth quarter 1987. The equation was expressed in double-log (natural logarithm) form except for the real interest rate variable. The raw real interest rate is used due to the presence of negative values. The coefficients of the variables were expressed as log-linear as these may then be interpreted as the elasticities of construction price.

The stability of the construction price equation was investigated by determining the 'rolling regression' of the dependent variable (after McNees [15]). Using this process, the construction price equations were re-estimated for each quarter using information (dependent and independent values) only up to the start of the relevant period.

The construction price equation was re-estimated up to the start of quarters from 1983:1 to 1990:2 using quarterly data from 1974:1. The first quarter of 1983 was chosen as the starting period so as to have a reliable degree of freedom.

The rest of this section reports the results of the estimated equations and summary statistics.

Results

The structural form of equation of construction price is presented in eqn (1).

$$\mathbf{ln}P_t = a_0+a_1\mathbf{ln}C^p_t+a_2\mathbf{ln}S^T_t+a_3\mathbf{ln}P^r_t+a_4\mathbf{ln}F^r_t+a_5R^r_t+a_6\mathbf{ln}M^p_t+a_7\mathbf{ln}U^e_t+a_8\mathbf{ln}Y^d+a_9O^L_t \quad (1)$$

The resulting estimated coefficients, standard deviations, lead periods and summary statistics are given in Table 2.

Table 2: Coefficient estimates

	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9
Coeff.	-3.614	0.807	0.009	-0.296	-0.258	-0.003	0.542	-0.136	0.606	0.061
Std dev.	0.941	0.238	0.003	0.085	0.029	0.001	0.232	0.029	0.164	0.014
Lead (t)		0	4	2	5	3	7	2	0	1

R = 0.986	R^2 (adjusted) = 0.966	SEE = 0.020	Durbin Watson = 2.172	$F_{9,43}$ = 164

Table 3 summarises the re-estimated construction price equation and relevant statistics. Attention is focused on the stability of this equation.

The Table shows that the coefficient of variation of regression coefficients of variables fall within 3 and 20%. The only exception is S^T regression coefficients. The R and Adjusted R^2 statistics are very stable with less than 1 per cent variability. The bivariate correlation coefficients were examined and, as none of the values exceeded 0.8 [17], no indication was found of multicollinearity.

Discussion

All the variables have the expected theoretical signs.

Adjusted R^2 of the equation, (adjusted coefficient of determination) indicates excellent fit with 97 per cent of the variance in the construction price being explained by the equations. Since the equation is log-linear, the standard error of the estimate implies an average within-sample prediction error of 2 per cent. DW shows no problem with first-order autocorrelation of the residuals since the DW statistics is comfortably near 2.0 (by Stewart [27] criteria).

The theoretical expectation is that general economic conditions, or growth in general economic conditions, induce construction demand and consequently an increase in construction price. The positive relationship between construction price and GNP is therefore expected (the GNP growth variable having been eliminated during the univariate analyses).

Estimating folklore would have the bid price as a product of input costs and mark-up, which implies that increases in costs will result in increases in prices. The positive relationship found between these two variables, even in partial correlations, satisfies this preconception.

Work stoppages in the construction industry have a positive relationship with construction price. This variable reduces construction supply and consequently increase the price.

The number of private construction firms registered has been used as a measure of the intensity of competition (Skitmore [23]) and affects construction supply. The greater the number of firms, it is argued, the greater the potential number of contractors expected to bid for a contract, which increase the actual and perceived intensity of competition. The higher the intensity of competition the lower, will be the price (McCaffer [12]; Neufville *et al* [16]), and hence the negative sign of this variable coefficient accords with *a priori* beliefs. It should be noted however, as the number of registered contractors has been consistently rising in the UK over the past twenty years, the extent to which it reflects increasing competition is not certain. It might, for example, simply reflect the extent of vertical disintegration in the industry - an increased number of sub-contractors not necessarily implying increased competition. Equally possible is that the increase in registrations is more a result of the sucess of the tax authorities' ability to track down evading companies than their level of competitiveness.

Productivity is expected to have a negative relationship with price, in which case the higher the productivity, the lower the unit cost that may be expected and consequently a lower price of construction. Its negative relationship at lead of two quarters in the equation is theoretically reasonable. Firms with high productivity are expected to have lower price level to improve the chances of winning more contracts. Another study by Akintoye and Skitmore [2] indicates a significant negative relationship between construction price and the future or expected productivity. These results suggest that the industry is interested in both future level of productivity and historical productivity level as they affect construction price.

Manufacturing profitability has an impact on the demand side of construction price. This has positive inelastic relationship with construction price. Interestingly, this corresponds with the New Cambridge School idea that company disposable income (undistributed profits) are a major determinant of fixed capital investment (and hence new construction output),

Unemployment has a negative inelastic relationship with construction price with a lead of 2 quarters. A likely interpretation of this centres around the notion than an increase in unemployment rate creates financial hardship and uncertainty. This uncertainty causes many potential clients of the construction industry to postpone initiating new construction works. This results in total decrease in the volume of construction available for construction contractors. A decrease in the construction volume is expected to result in a decrease in construction price as there will be more contractors chasing fewer work.

The dummy variable for the oil crisis has a positive and lead of 1 quarter with construction price. This has a coefficient of 0.061.

The observed residuals of the equation were approximately random and normally distributed. The expected values of the residuals and standardized residuals were zero with standard deviations of 0.0182 and 0.9094 respectively. The mean leverage value was 0.1698 (0.0927 standard deviation). Only one case had a leverage value above the critical value of 0.3396. The outliers were not obviously patterned and only two cases from the 60 cases had a standardized value greater than 2 or less than -2, which is less than the 5 per cent one would expect by chance.

In summary, the construction price equation generally conformed with our intuitions and the OLS multiple regression assumptions in all details.

Part 2: the simultaneous model

Construction supply and demand

In focusing on the interactions of construction demand and supply in relation to construction price we assume that firms in the construction industry are perfectly endowed with the same current and past price level and quantity information about the construction market. This appears to be reasonable as firms are generally formally or informally conscious of the general movements in economic conditions and general price level. Also, organisations (private and public) abound that provide information on the activities of the construction industry. As a result, and despite the fact that construction ranges from monopolistic competition to oligopoly, it is often assumed that the construction market is "perfectly" competitive (cf., Hillebrandt [11]) thus enabling the economic theory of price mechanism to be invoked for the determination of construction price.

Construction production takes some time. Suppliers of construction have to decide today how much they will put on the market in the next time periods. Output decisions are made based on what are believed to constitute the explanatory variables of construction supply. Hence, we model the supply of construction by the equation (Skitmore and Akintoye [25]):

$$\mathbf{ln}\ Q^{s*}_t = a_0 + a_1\ \mathbf{ln}\ P_t + a_2\ \mathbf{ln}\ P^R_t + a_3\ \mathbf{ln}\ C^p_t + a_4\ \mathbf{ln}\ S^T_t + a_5\ \mathbf{ln}\ F^r_t + V_t \qquad (2)$$

Where Q^s is the logarithm of construction supply at time t. a_1, a_2, a_3, a_4, and a_5 are elasticities with respect to price, productivity, input cost, strikes and registered private construction firms; and V is a random shock to production of construction output whose first difference is normally distributed with mean zero and constant variance which, are serially and mutually uncorrelated.

Demand for construction at time t is modelled by (Akintoye [3]):

$$\mathbf{ln}\ Q^d_t = b_0 + b_1\ \mathbf{ln}\ P_t + b_2\ \mathbf{ln}\ Y^d_t + b_3\ r_t + b_4\ \mathbf{ln}\ U^e_t + b_5\ \mathbf{ln}\ M^p_t + U_t \qquad (3)$$

Where Q^d is the logarithm of demand for construction at the time t. b_1, b_2, b_4, and b_5 are the elasticities of price, GNP, unemployment and manufacturing profitability; b_3 is the coefficient of real interest rate and U is a random shock to construction demand whose first difference is normally distributed with mean zero and constant variance which, are serially and mutually uncorrelated.

The estimated equations (2) and (3) are as follows (Skitmore and Akintoye [25]; Akintoye [3]):

$$\mathbf{ln}\ Q^s_t = 1.049 + 0.970\ \mathbf{ln}\ P_t + 0.628\ \mathbf{ln}\ P^R_{t-4} - 0.695\ \mathbf{ln}\ C^p_{t-2} - 0.019\ \mathbf{ln}\ S^T_{t-3} + 0.239\ \mathbf{ln}\ F^r_{t-8}\ 0.093 G^L_{t-1} \qquad (4)$$

$$\mathbf{ln}\ Q^d_t = -14.051 - 0.766\ \mathbf{ln}\ P_{t-3} + 1.632\ \mathbf{ln}\ Y^d_t - 0.011\ r_{t-1} - 0.249\ \mathbf{ln}\ U^e_{t-4} + 1.764\ \mathbf{ln}\ M^p_{t-4} \qquad (5)$$

Equilibrium

Construction output decisions depend on a firm's knowledge of the movements of relevant explanatory variables. Decisions on construction output and construction demand movements/shocks determine the equilibrium price of construction at time t. Formally, the equilibrium price may be obtained by equating Eqn 2 and 3 and solve for P_t.

That is

$$Q^s_t = Q^d_t \qquad (6)$$

Construction supply and construction demand are not likely to be equal at time t as the construction demand at time t continues to filter into construction supply in the following periods (Butler [7]; Anon [4]). The greater the construction demand at time t, the greater the construction supply expected from time t to the following quarters. In other words, construction demand can be taken to be a leading indicator of construction supply.

This suggests a distributed lag model of the form:

$$Q^s_t = f(Q^d_t, Q^d_{t-1}, Q^d_{t-2}, ..., Q^d_{t-m}) \quad (7)$$

Thus, construction price estimates may be obtained by equating (2) (estimated as (4)) and (3) (estimated as equation (5)) using (7) and solving simultaneously for P_t. The equation of P_t derived in this way is termed here the **reduced-form** equation of construction price.

Construction supply - demand distributed lag estimation

Our *a priori* assumption is that the current value of construction supply depends not only on the current value of construction demand but also on the lags of construction demand. That is:

$$Q^s_t = \alpha + ß_0Q^d_t + ß_1Q^d_{t-1} + ß_2Q^d_{t-2} + ... + ß_mQ^d_{t-m} + U_t \quad (8)$$

In a general distributed lag formulation, the number of lags (m) may be either infinite or finite depending on the expected relationship between the dependent and the lagged explanatory variables. For the construction supply-demand relationship a finite lag distribution is expected. Hence, within a specific lag period, the effects of current construction demand should have completely filtered into construction supply.

In econometric studies, different methods of distributed lag relationships are available (Stewart and Wallis [26]; Thomas [28]; and Stewart [27]). Thomas [28] classified these as:

- *Geometric lag distributions*. An example of this is the Koyck geometric lag model that assumes that the coefficients of the lags decline geometrically indefinitely into the past.

o *OLS estimated lag distribution*.

o *Almon polynomial lag* (a generalised Leeuw's inverted 'V' distribution approach) (see Stewart and Wallis [26]; Thomas [28]; and Stewart [27]).

To establish the distributed lag relationship between construction supply and construction demand, the OLS estimated lag distribution and Almon polynomial lag methods were adopted on the *a priori* assumption of finite relationship. The geometric lag distribution with infinite relationship was considered inappropriate for this relationship

(1) OLS estimated distributed lag relationship

Using the SPSSX OLS multiple regression analysis, 13 potential explanatory variables based on the lagged Q^d were created (Q^d_t, Q^d_{t-1}, Q^d_{t-2}, ... Q^d_{t-12}). The construction supply Q^s was then regressed against these lagged Q^d using the Forward Stepwise Method with default tolerance values. The final equation derived through this procedure was:

$$Q^s_t = 3.436 + 0.198Q^d_t + 0.181Q^d_{t-1} + 0.118Q^d_{t-2} - 0.066Q^d_{t-3} + 0.028Q^d_{t-4} + 0.135Q^d_{t-5}$$

$$R^2 = 0.881 \qquad \text{Adjusted } R^2 = 0.747 \qquad (9)$$

The sum of the coefficient weights in (9) is 0.594 (ie 0.198 + 0.181 + 0.118 - 0.066 + 0.028 + 0.135), whereas unity is expected if construction demand effects are totally filtered into construction supply (after Thomas [28]), or in a situation where construction supply is predominantly an outcome of the construction demand only.

The DoE definition of construction output (used as proxy for construction supply) and construction new orders (proxy for construction demand) shows that some items of work included in construction output are not considered in the definition of construction new orders as highlighted below. On the other hand, the long run interpretation of the result shows that the recorded construction new orders only constitute 60% of the construction output.

This OLS method of distributed lag estimation has, however, been criticised as being faulted with problems of multicollinearity. It is expected that the coefficients of the explanatory variables based on this method will have large standard errors so that it becomes extremely difficult to separate out the effect of the different lags (Stewart and Wallis [26]).

(2) Almon Polynomial Distributed Lag method

Rather than assuming that the weighting of the coefficients declines geometrically, as does the Koyck geometric lag distribution for example, the Almon Polynomial lag distribution imposes some form of approximating polynomial on the coefficients $ß_i$ (8). The type of the polynomial may be such that the coefficient weighting increases until it reaches a peak and then decline (2nd degree polynomial - with one turning point). Alternatively, the coefficients weighting increase until it reaches a peak, then decline only to peak again (3rd degree polynomial - with two turning point) or any other forms of polynomial.

The Almon polynomial lag assumes a finite lag length relationship between the dependent and the lagged explanatory variables. So also, the degree of the polynomial has to be at least one more than the number of the turning points in the curve. The degree of the polynomial to use may depend on the lag length particularly where the lower degree polynomial will not give a true relationship between the $ß_i$.

With the quarterly data of construction supply and construction demand, alternative relationships between the $ß_i$ were considered. These vary for the finite lag length between 3 and 8 different maximum lag lengths, that is, s=3,4,5,6,7 and 8; and two to seven degree polynomial.

For example in case of Poly32, (Poly32 has three quarter lag length and second degree polynomial relationship between construction supply and the construction demand) the following indicates the process of arriving at the $ß_i$ relationship.

$$Q^s_t = \alpha + ß_0 Q^d_t + ß_1 Q^d_{t-1} + ß_2 Q^d_{t-2} + ß_3 Q^d_{t-3} + U_t \quad (10)$$

Hence

$$ß_i = \varphi_0 + \varphi_1 i + \text{........}\varphi_s i^s \quad (11)$$

However, s=3 in this case. We use second degree polynomial

$$b = \varphi_0 + \varphi_1 i + \varphi_2 i^2 \quad (12)$$

which passes through the four points corresponding to the values $ß_0$, $ß_1$, $ß_2$, and $ß_3$.

Using (10) and (11), we have

$$\begin{aligned} ß_0 &= \varphi_0 \\ ß_1 &= \varphi_0 + \varphi_1 + \varphi_2 \\ ß_2 &= \varphi_0 + 2\varphi_1 + 4\varphi_2 \\ ß_3 &= \varphi_0 + 3\varphi_1 + 9\varphi_2 \end{aligned} \quad (13)$$

(10) becomes

$$Q^s_t = \alpha + \varphi_0 Q^d_t + (\varphi_0 + \varphi_1 + \varphi_2)Q^d_{t-1} + (\varphi_0 + 2\varphi_1 + 4\varphi_2)Q^d_{t-2} + (\varphi_0 + 3\varphi_1 + 9\varphi_2)Q^d_{t-3} + U_t \quad (14)$$

Rearranging (14) gives

$$Q^s_t = \alpha + \varphi_0(Q^d_t + Q^d_{t-1} + Q^d_{t-2} + Q^d_{t-3}) + \varphi_1(Q^d_{t-1} + 2Q^d_{t-2} + 3Q^d_{t-3}) + \varphi_2(Q^d_{t-1} + 4Q^d_{t-2} + 9Q^d_{t-3}) \quad (15)$$

Using (15), the parameters φ_0, φ_1 and φ_2 were then estimated using OLS regression analysis. Having obtained these, $ß_0$, $ß_1$, $ß_2$, and $ß_3$ were calculated using (13).

The same principle was adopted for the alternative $ß_i$ relationships considered in this work for maximum lag lengths 3,4,5,6,7 and 8; and polynomial degrees 3,4,5,6 and 7. The results showed that the estimation of parameters φ_i, based on more than third degree polynomial and lag length more than 7 quarters, are insignificant and failed to pass the tolerance test based on the OLS Forward Stepwise regression analysis. Hence, $ß_i$ relationships over 7 lag length and three polynomial degrees were not considered further in our analysis.

The estimation of φ_i carried out are denoted as follows: Poly31, Poly32, Poly43, Poly53, Poly63, and Poly73.

The results of the OLS estimation for φ_i are shown in Table 4 The standard errors of the φ_is are shown in parentheses.

Using the values of φ_i (where i = 0, 1, 2, 3) in Table 4 and based on Eqn 16, the $ß_i$ relationship for each of the Poly-models were derived as shown in Table 5.

The sums of $ß_i$ weighting in Table 5, ranging between 0.554 and 0.610, compare favourably with the value of 0.594 obtained using the OLS method of distributed lags estimation. This Almon polynomial lag analysis assures us of one of two things, (1) construction new orders (demand) can only account for about 60% of the construction output (supply), or (2) only 60% of the construction demand are converted to construction supply.

Using the maximum total $ß_i$ weighting as the criteria for the choice of the $ß_i$ relationship, Poly63 appeared to be favoured. The positive sign of all the coefficients is also favoured in terms of the lag structure and the *a priori* expectation based on the activity of the construction industry.

The model indicates that the level of construction demand has an instant impact on construction supply. This then tails off until the t+5 quarter with a little rise noticed at t+6. This accords with our intuitions in that, for example, contractors are most likely to increase construction output in the times of construction boom to make instant profits. As the boom starts declining, firms are also likely to support a declining output. This is not only to keep the key workforce occupied but also to ensure the firms' continued survival until the construction demand peaks up again.

The final model was

$$Q^s_t = 3.281 + 0.197Q^d_t + 0.158Q^d_{t-1} + 0.106Q^d_{t-2} + 0.055Q^d_{t-3} + 0.02Q^d_{t-4} + 0.016Q^d_{t-5} + 0.058Q^d_{t-6} \quad (16)$$

Reduced-form equation

The simultaneous equations of construction price were as follows (17), (18) and (19).

$$Q^d_t = -14.051 - 0.766P_{t-3} - 0.249U^E_{t-5} + 1.764M^p_{t-4} - 0.011R^r_{t-1} + 1.632Y^d \qquad \text{Demand equation (17)}$$

$$Q^s_t = 1.049 + 0.970P_t + 0.628P^r_{t-4} - 0.695C^p_{t-2} - 0.019S^T_{t-3} + 0.239F^r_{t-8} - 0.093O^L_{t-1} \qquad \text{Supply equation (18)}$$

$$Q^s_t = 3.281 + 0.197Q^d_t + 0.158Q^d_{t-1} + 0.106Q^d_{t-2} + 0.055Q^d_{t-3} + 0.02Q^d_{t-4} + 0.016Q^d_{t-5} + 0.058Q^d_{t-6} \qquad \text{Equilibrium equation (19)}$$

P (tender price level) in these equations is an endogenous variable. Substituting the demand equation (17) into the equilibrium equation (19) and letting this equal the supply equation (18), a little algebra produces:

$$\begin{aligned} P = {} & -6.424 - 0.647P^r_{t-4} + 0.716C^p_{t-2} + 0.0196S^T_{t-3} - 0.246F^r_{t-8} + 0.096O^L_{t-1} \\ & - (0.155P_{t-3} + 0.125P_{t-4} + 0.083P_{t-5} + 0.043P_{t-6} + 0.015P_{t-7} + 0.012P_{t-8} + 0.046P_{t-9}) \\ & - (0.050U^E_{t-4} + 0.041U^E_{t-5} + 0.027U^E_{t-6} + 0.014U^E_{t-7} + 0.005U^E_{t-8} + 0.004U^E_{t-9} + 0.015U^E_{t-10}) \\ & + (0.357M^p_{t-4} + 0.287M^p_{t-5} + 0.192M^p_{t-6} + 0.099M^p_{t-7} + 0.035M^p_{t-8} + 0.028M^p_{t-9} + 0.105M^p_{t-10}) \\ & - (0.002R^r_{t-1} + 0.002R^r_{t-2} + 0.001R^r_{t-3} + 0.0006R^r_{t-4} + 0.0002R^r_{t-5} + 0.0002R^r_{t-6} + 0.0006R^r_{t-7}) \\ & + (0.331Y^d + 0.266Y^d_{t-1} + 0.178Y^d_{t-2} + 0.091Y^d_{t-3} + 0.032Y^d_{t-4} + 0.026Y^d_{t-5} + 0.097Y^d_{t-6}) \qquad (20) \end{aligned}$$

Discussion

(20) is the reduced-form equation for construction price. The coefficients in the reduced-form equation are called reduced-form coefficients. These are functions of the structural coefficients, that is, the parameters of the reduced-form equations are themselves functions of the parameters of the underlying structural system. The reduced-form models have neither direct nor unique economic interpretation. Reduced-form models predict what will happen when one or more exogenous variables change, and they do not necessarily produce a particular explanation of how or why. In essence, the reduced-form equations, apart from being consistent estimates of structural coefficients, are used for forecasting macroeconomic variables.

Conclusion

This paper describes the derivation of construction price equations using two systems of equations comprising (1) the single structural form, and (2) the simultaneous supply/demand form. A review is provided of the price determination mechanism under market forces in a free economy and the question of how demand and supply combine to influence prices is considered.

A single structural form of construction price equation was derived. The model seems to be satisfactory in several counts, (1) It is statistically significant, (2) it has some theoretical basis. The model has R^2 adjusted value of 0.97 for the deflated data with acceptable Durbin-Watson statistics.

The stability of the model was investigated by producing 'rolling regression' of the dependent variable. Using this process, construction price equations were re-estimated each quarter using only information from 1974 first quarter up to the start of the quarter being considered.

Coefficients of variation of the regression coefficients for each independent variables were obtained to determine the stability of the equation. Further examination of the equation indicated that the necessary assumptions for OLS regression to be reasonably satisfied.

The reduced-form equation of construction price was derived from the simultaneous construction supply, demand and equilibrium equations. The equilibrium relationship between construction supply and demand is of distributed lag with construction demand responsible for 60 per cent values of construction supply though 100 per cent is expected.

The construction industry is one of the largest industries in most of the countries throughout the world. It is also one of the most volatile in economic terms - with extreme behaviour in both good and bad times. Understanding the nature of such behaviours is crucial at both macro and micro levels in the management of the industry and its constituent organisations. As yet, surprisingly little substantive work has been carried out aimed at deriving suitable predictive or even explanatory models, all economic reports being essentially intuition based.

The work described in this paper is, hopefully, the first of many approaches to modelling the construction industry's economic forces. As first attempts go, we believe ours has been surprisingly successful. The development of single structural form model with R^2 adjusted values of 0.97 for deflated data of these kind is most encouraging and bodes well for future work in the field. Our most recent work, not reported here, indicates that the reduced form model is likely to be better than all other current methods, including our single form equations, at construction price forecasting (Akintoye [3])

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Data Appendix

Q^d Quarterly construction new orders. This is a measure of construction demand. Other measures of construction demand include value of building approvals (Runeson, 1988) and gross floor area of construction start (Tan, 1989).

Source: HMSO 1974-1989 "Value at current prices of New-order obtained" *Housing and construction statistics,* December, Part 2 pp. 4.

P Quarterly Tender price index. This measures the trend of contractors' price levels in accepted tenders for new works.

Source: *Building Cost Information Service* (BCIS), 1990 "Indices -introduction" Building cost information service manual. Section ABb6, June.

Y^d Quarterly gross national product. This a measure of general economic condition. The raw data or rate of change may be used.

Source: *Economic Trend* annual supplement, 1989 Edt, pp.12.

Rr Real rate of interest. This is calculated as the difference between the nominal interest rate and the rate of inflation as measured by the quarter to quarter change in retail price index.

Source: (for quarterly nominal interest rate and inflation rate) *Datastream International Ltd On-line*, A company of Dun and Bradstreet corporation.

M^p Manufacturing output price/input cost ratio. This is used as a measure of profitability of this sector of an economy.

Source: *Datastream International Ltd* On-line, A company of Dun and Bradstreet corporation.

U^e Unemployment - Unemployment figures refer to numbers claiming unemployment-related benefit at Unemployment Benefit Offices.
Source: *Economic Trend Annual Supplement*, 1990 Edt., pp.112-114.

Q^s Quarterly construction output. This is a measure of construction supply. Source: HMSO 1974-1989 "Value at current prices of construction output" *Housing and construction statistics*, December, Part 2.

F^r Number of registered Private Contractors. Source: HMSO 1974-1989 "Private contractors-Number of firms" *Housing and Construction Statistics*, Annual supplement, December.

P Quarterly Tender Price Index. This measures the trends of contractors' pricing level in accepted tenders for new works. Source: *Building Cost Information Service* (BCIS), 1990 "Indices -introduction" Building cost information service manual. Section ABb6, June.

C^p Quarterly Building Cost Index. This measures changes in costs of labour, material and plant. Source: *Building Cost Information Service*, (1990) "Indices" Section ABb6, June.

S^T This is the working days lost by workers both directly or indirectly involved in operation of construction industry due to industrial disputes. Source: *UK Employment Gazette*, (1974-1989) "Industrial disputes", December

P^r Output per person employed in the construction industry has been used to capture the trend in the productivity level. Butler (1978), for example, used a measure of gross output per person as the best way of adjusting labour cost index for variations in productivity from quarter to quarter. Source: *UK Employment Gazette*, (1974-1989) "Employment - Indices of output, employment and output per person", October.

O^L Dummy variable to reflect general increase in prices between 1978 and 1980 due to oil crisis (During this period of oil shock, the real price of crude oil went up by 110 per cent): equal 1 between 1978:2 and 1980:2 and zero otherwise.

SOURCES OF DATA USED IN THE MODELS IN TABULATED FORM

Variables	Abreviations	Sources
1. Level of Unemployment (CSO)	U^E	Economic Trends and Employment Gazette
2. Construction Output	Q^s	Housing and Construction Statistics (CSO)
3. Ratio of Price to Cost Indices in Manufacturing	M^p	Economic Trends (CSO)
4. Building Cost Index	C^p	Building Cost Information Service Quarterly Bullettin
5. Construction Neworder	Q^d	Housing and Construction Statistics (CSO)
6. Gross National Product	Y^d	Economic Trends (CSO)
7. Bank Base Rate		Economic Trends, Financial Statistics,
8. Retail Price Index		Datastream Internationsl Ltd
9. Real Interest Rate (Bank Base Rate - Inflation)	R^r	On-Line (A company of Dun and Bradstreet corporation)
10. Work Stoppage in the construction industry	S^T	Economic Trends (CSO)
11. Output per Person Employed - construction industry (Productivity)	P^r	Employment Gazette (CSO)
12. Number of Registered Private Contractors	F^r	Housing and Construction Statistics (CSO)
13. Tender Price Index	P	Building Cost Information Service Quarterly Bullettin

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Table 1. Construction demand and supply determinants lead relationships with TPI.[a]

Construction Demand and supply Determinants	Aggregated Analysis 1974 - 1986 52 Quarters	Disaggregated Analysis 1974 - 1979 24 Quarters	1980 - 1985 24 Quarters	1986 - 1990 18 Quarters	Choice of optimum Lead based on consistency of leads in both aggregated and disaggregated analysis
MAN (M^p)	1 - 7	5, 6	6, 7, 8	5, 6	Inconclusive
EMP (U^e)	0 - 3	0, 1, 2, 5	1, 2, 5, 6, 7	3, 4	Inconclusive
GNP (Y^d)	0	0, 1	0, 4, 5	0	0
FRM (F^r)	5	0	7	0 - 7	Inconclusive
BCI (C^p)	0, 1	0	-	0, 2, 4	0
STR (S^T)	0, 5	-	7	-	Inconclusive
PRO (P^r)	2, 5, 6	2	2	-	2
RIR (R^r)	5 - 7	-	-	2, 3	Inconclusive

[a]Significant lead relationships are established with construction price at the following lead (Significant level being 95%)

Table 3. Construction price models showing stability of (1).[a]

		Const.	C^P	S^T	P^r	F^r	M^P	r	U^e	Y^d	O^L	R	Adj. R^2	SEE	D-W	F-Value	D.F	Data (Qrts)
1983	1	-5.236	0.604	0.005	-0.174	-0.240	0.882	0.003	-0.126	0.690	0.051	0.982	0.949	0.023	2.223	61.0	9,20	37
	2	-5.245	0.605	0.006	-0.155	-0.227	0.891	0.003	-0.126	0.696	0.050	0.984	0.954	0.022	2.292	70.1	9,21	38
	3	-5.125	0.582	0.005	-0.195	-0.256	0.883	0.003	-0.122	0.679	0.053	0.985	0.958	0.022	2.307	79.6	9,22	39
	4	-5.110	0.590	0.004	-0.182	-0.247	0.892	0.003	-0.126	0.681	0.051	0.986	0.961	0.021	2.322	88.5	9,23	40
1984	1	-5.187	0.592	0.004	-0.203	-0.241	0.903	0.003	-0.126	0.683	0.051	0.986	0.963	0.021	2.317	96.8	9,24	41
	2	-5.096	0.585	0.004	-0.207	-0.258	0.821	0.003	-0.130	0.699	0.053	0.987	0.965	0.021	2.336	105.6	9,25	42
	3	-5.027	0.596	0.004	-0.203	-0.254	0.824	0.003	-0.130	0.699	0.053	0.988	0.967	0.020	2.336	115.1	9,26	43
	4	-4.983	0.562	0.004	-0.200	-0.240	0.873	0.003	-0.130	0.722	0.051	0.988	0.967	0.020	2.306	119.3	9,27	44
1985	1	-4.820	0.583	0.003	-0.203	-0.255	0.805	0.003	-0.134	0.704	0.053	0.988	0.967	0.020	2.251	122.9	9,28	45
	2	-4.817	0.530	0.004	-0.207	-0.248	0.806	0.003	-0.129	0.707	0.052	0.988	0.967	0.020	2.202	127.9	9,29	46
	3	-4.865	0.541	0.003	-0.204	-0.252	0.809	0.003	-0.134	0.718	0.053	0.988	0.969	0.020	2.241	134.9	9,30	47
	4	-4.850	0.535	0.003	-0.202	-0.251	0.809	0.003	-0.134	0.718	0.053	0.988	0.969	0.020	2.262	142.1	9,31	48
1986	1	-4.760	0.619	0.004	-0.213	-0.258	0.768	0.003	-0.133	0.667	0.054	0.988	0.968	0.020	2.184	140.4	9,32	49
	2	-4.687	0.638	0.004	-0.219	-0.259	0.758	0.003	-0.133	0.659	0.055	0.988	0.970	0.020	2.210	149.0	9,33	50
	3	-4.805	0.634	0.004	-0.217	-0.257	0.760	0.003	-0.135	0.670	0.054	0.988	0.970	0.020	2.222	155.6	9,34	51
	4	-4.539	0.679	0.005	-0.225	-0.260	0.768	0.003	-0.129	0.624	0.055	0.988	0.970	0.020	2.195	156.5	9,35	52
1987	1	-4.385	0.708	0.005	-0.235	-0.260	0.738	0.003	-0.130	0.614	0.056	0.988	0.970	0.020	2.273	160.9	9,36	53
	2	-4.041	0.793	0.006	-0.271	-0.259	0.627	0.003	-0.137	0.606	0.058	0.987	0.967	0.021	2.242	151.2	9,37	54
	3	-3.664	0.800	0.009	-0.299	-0.258	0.534	0.003	-0.137	0.609	0.061	0.986	0.965	0.021	2.123	144.9	9,38	55
	4	-3.637	0.803	0.009	-0.299	-0.258	0.533	0.003	-0.137	0.605	0.061	0.986	0.965	0.021	2.170	149.3	9,39	56
1988	1	-3.629	0.803	0.009	-0.299	-0.258	0.532	0.003	-0.137	0.605	0.061	0.986	0.965	0.021	2.170	153.2	9.40	57
	2	-3.643	0.802	0.009	-0.298	-0.258	0.538	0.003	-0.136	0.604	0.061	0.986	0.966	0.021	2.167	157.1	9,41	58
	3	-3.620	0.800	0.009	-0.297	-0.258	0.537	0.003	-0.137	0.613	0.061	0.986	0.966	0.020	2.170	160.6	9,42	59
	4	-3.614	0.807	0.009	-0.296	-0.258	0.542	0.003	-0.136	0.606	0.061	0.986	0.966	0.020	2.172	164.3	9,43	60
1989	1	-3.605	0.810	0.009	-0.295	-0.258	0.542	0.003	-0.135	0.603	0.061	0.986	0.966	0.020	2.172	168.3	9,44	61
	2	-3.658	0.817	0.009	-0.294	-0.262	0.553	0.003	-0.130	0.590	0.062	0.986	0.965	0.020	2.162	168.8	9,45	62
	3	-3.648	0.813	0.009	-0.295	-0.263	0.552	0.003	-0.129	0.593	0.062	0.986	0.966	0.020	2.172	172.5	9,46	63
	4	-3.743	0.815	0.011	-0.299	-0.275	0.592	0.003	-0.122	0.592	0.065	0.984	0.962	0.021	2.095	157.0	9,47	64
1990	1	-3.848	0.813	0.009	-0.283	-0.291	0.776	0.002	-0.124	0.578	0.064	0.981	0.955	0.022	1.757	134.6	9,48	65
	2	-4.444	0.817	0.007	-0.284	-0.311	0.837	0.002	-0.118	0.542	0.065	0.976	0.944	0.025	1.525	110.6	9,49	66
Mean		-4.414	0.689	0.242	-0.242	-0.258	0.723	0.003	-0.131	0.646	0.057	0.986	0.964	0.021	2.185	133.9		
Std		0.624	0.109	0.002	0.047	0.015	0.137	0.000	0.005	0.051	0.005	0.003	0.006	0.001	0.161	30.3		
CV(%)		14.125	15.802	39.690	19.563	5.699	18.912	8.504	3.930	7.823	8.386	0.259	0.640	5.374	7.369	22.6		
Excluding 1983 regression coefficients and statistics																		
Mean		-4.297	0.704	0.006	-0.252	-0.260	0.698	0.003	-0.132	0.640	0.058	0.986	0.965	0.021	2.170	143.1		
Std		0.587	0.110	0.003	0.042	0.014	0.130	0.000	0.005	0.051	0.005	0.003	0.005	0.001	0.167	20.5		
CV(%)		13.655	15.636	40.751	16.822	5.311	18.567	9.116	3.735	8.042	7.894	0.262	0.545	7.074	7.698	14.3		

[a]underlined regression coefficients are insignificant at 5% confidence level.

Table 4. φ_i and statistics.

	α	φ_0	φ_1	φ_2	φ_3	r^2	adj	Rmse	F val.	D.F	DW
Poly31	3.568	0.218	-0.049			0.86	0.736	0.050	78.99	2,54	0.87
	(0.325)	(0.044)	(-0.028)								
Poly32	3.596	0.148	0.156	-0.068		0.87	0.746	0.049	55.94	3,53	0.83
	(0.319)	(0.057)	(0.117)	(0.038)							
Poly43	3.410	0.110	0.392	0.278	0.045	0.88	0.751	0.049	42.40	4,51	0.78
	(0.335)	(0.063)	(0.205)	(0.132)	(0.218)						
Poly53	3.468	0.153	0.169	-0.132	0.020	0.89	0.756	0.046	42.77	4,50	0.508
	(0.334)	(0.054)	(0.122)	(0.060)	(0.008)						
Poly63	3.281	0.197	-0.0267	-0.0144	0.0025	0.86	0.720	0.049	35.14	4,49	0.669
	(0.397)	(0.064)	(0.011)	(0.043)	(0.005)						
Poly73	3.591	0.141	-0.071	0.034	-0.004	0.88	0.748	0.047	39.56	4,48	0.670
	(0.421)	(0.063)	(0.101)	(0.035)	(0.003)						

Table 5. Coefficients weighting in relation to Polys'.

	α	$ß_0$	$ß_1$	$ß_2$	$ß_3$	$ß_4$	$ß_5$	$ß_6$	$ß_7$	
Poly31	3.568	0.218	0.169	0.119	0.070					
Poly32	3.596	0.148	0.241	0.188	0.004					
Poly43	3.410	0.110	0.269	0.138	-0.012	0.084				
Poly53	3.468	0.153	0.210	0.120	0.001	-0.029	0.148			
Poly63	3.281	0.197	0.158	0.106	0.055	0.020	0.016	0.058		
Poly73	3.591	0.141	0.100	0.102	0.120	0.129	0.103	0.016	-0.157	0.554