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A theoretical framework for determining the minimum number of bidders in construction bidding competitions

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Abstract

A theoretical framework for determining the minimum number of bidders in competition for projects in the construction industry is proposed. This is based on the neo-classical micro-economic theory for price determination in construction and the assumption of random contractor-selection. Empirical analysis of the Hong Kong data set not only illustrates the applicability of the framework, but also supports the relevance of the microeconomic model for construction price determination. The main implication for clients is that, in order to obtain the most competitive bids for projects in the most cost efficient way, they should vary the minimum number of bidders in competition according to market conditions.

Keywords

Construction price determination, tendering theory, construction economics, number of bidders

Introduction

This paper proposes a theoretical framework for determining the minimum number of contractors in competition for projects in the public contracting sector of the Hong Kong construction industry. The framework aims to provide a more cost effective approach for the Hong Kong Special Administrative Region (HKSAR) Government to obtain competitive bids while continuing to maintain its public accountability. In order to provide a theoretical foundation for the framework, the linkage between market conditions and the degree of competition is explored. Based on the neo-classical micro-economic theory for construction price determination, it is suggested that the number of potential competitors in competition will depend on the market conditions. A set of regression models is formulated to estimate the number of potential competitors in the market. Following from this, the minimum number of contractors to be included in competition is determined. This is based on the assumption that the contractor-selection process is random. The framework, however, does not quantify the cost effects of additional number of contractors in bidding competition for projects. An analysis of a data set from the HKSAR Government further confirms the applicability of the framework.

Since there is a large amount of literature on tendering theory, it is not realistic to expect a paper of this format to provide a comprehensive literature review, particularly, on the debate on the relevance of tendering theory and micro-economic theory for construction price determination (see Runeson and Raftery, 1998, for a thorough literature review). Reference to the literature is made whenever appropriate. The primary purpose of this paper is to construct a framework for determining the minimum number of bidders in competition and to conduct an empirical analysis for testing the applicability of the framework.

Construction price determination

The construction economics literature containstwo fundamentally different approaches to construction price determination. The first is the probabilistic approach that originated from Friedman in 1956 and has gained wide publicity. There is a large amount of literature, that has become known as tendering theory, on the analysis of how construction prices are determined (eg., Gates 1967, 1970, 1976a, 1976b, 1979; Rosenshine 1972; Dixie, 1974; Fuerst 1976, 1977, 1979; Weverbergh 1978; Benjamin and Meador 1979; Carr 1982, 1987.). .

The second approach, by Hillebrandt (1974), follows the neo-classical micro-economic theory of price determination in construction. A more comprehensive literature review and evaluation on the relevance of neo-classical micro-economic theory for construction price determination in the building industry was conducted by Runeson and Raftery (1998). They concluded that the neo-classical micro-economic theory is a more suitable analytical framework than tendering theory, both in terms of its predictions and in the conformity with empirical studies of the construction industry. It is outside the scope of this paper to further evaluate the appropriateness of the neo-classical micro-economic theory for construction price determination. Instead, this line of thinking forms the basis for the proposed empirical study.

The basic assumption for application of neo-classical micro-economic theory in construction is that the building industry is very competitive and conforms to the model of perfect competition. A perfectly competitive market is characterized by the fact that there is a “going market price” (i.e. perceived equilibrium price) which all buyers pay and all sellers receive, and no one player in the market can individually affect that price. In other words, each buyer and each seller is much too small a part of the overall market to have their actions affect the market price. Other standard descriptions of such market include homogeneity of the product, perfect information and easy entry to and exit from the market. Here the market can be considered as a process of interaction between buyers and sellers of a commodity for a mutually agreed price (Perman *et. al.* 1999). A direct analogy in construction would be that the sellers are construction clients either from the public or private sectors who put contracts on the market in return for the construction services required to construct facilities to customized designs specified by the clients. The buyers are construction companies (or contractors) who obtain the contracts in return for a sum of money provided by the clients. Most contracts are awarded through competitive tendering processes where clients and contractors reach a mutually agreed price. Normally the contractors who submit lowest tender prices obtain the contracts.

In this competitive market, price determination is based on interaction of demand and supply. The market price for a commodity is the equilibrium price where the downward-sloping demand curve and the upward-sloping supply curve intersect. The construction industry responds to changes in demand in the short run by changing the price of its product and in the long run by a change in the capacity of the industry. On an a *priori* basis, it is assumed that firms in the industry would only tender when they have, or anticipate, excess capacity and would not tender when all capacity is being utilized.

Consider a reduction in demand in the construction industry; lower prices will result initially because of the lower capacity utilization in the industry. The unutilized capacity in the industry will lead to lower marginal costs. The lower the marginal costs, the higher the opportunity costs of losing projects for individual firms and hence the lower the tender prices. As a result, competitiveness increases. In the long run, the industry will reduce the excess supply capacity because of insufficient profit and prices will be restored to their initial level. On the other hand, an increase in demand in the construction market will result in higher capacity utilization in the industry. The higher capacity utilization results in higher marginal costs and hence lower opportunity costs of not winning projects and hence the higher the tender prices. In the long run, the industry supply capacity will be adjusted and prices and profits will return to their initial level.

Number of potential competitors as a measure of degree of competition

Based on the above price determination model for the construction industry, changes in demand and/or supply will change the degree of competitiveness in the industry initially and result in movements in tender price level. In the long run, however, the supply capacity will be adjusted and prices will be restored. In this way, the degree of competition must be measured in terms of capacity utilization rather than in terms of the total level of output (Runeson and Bennett, 1983). In addition, it is a reasonable assumption that the number of potential competitors in the market is a reflection of supply capacity utilization in the industry. In line with this basic assumption, Runeson (1988) has estimated empirically that prices systematically changed by more than $\pm$ 20% over the economic cycle and that 85% of these price changes could be explained by variables describing market conditions such as changes in demand and capacity utilization in industry. Therefore, the degree of competition in the industry can be measured in terms of the likely number of potential competitors for projects in the market and the degree of competition will depend on the market conditions.

There is much empirical evidence showing that market conditions affect tendering behavior (e.g. De Neufville, *et. al.* 1977; Flanagan and Norman, 1985; Runeson, 1990; Rawlinson and Raftery, 1997). The market conditions affect at least the contractors' bid prices and number of competitors for a project. These are obvious as the price determination model suggested previously. De Neufville *et. al.* (1977) have shown that in a boom period (which they refer to as 'good' years) when there are more projects available in the construction market, contractors generally bid for projects at higher profit margins and competition for projects is relatively less intense. In a slump period (i.e. referred to as 'bad' years) with fewer projects available, contractors bid lower than in the boom period and competition becomes more intense. They have further shown that market conditions affect the number of competitors for a project. Interestingly enough, it is shown that the market conditions affect contractors' bid prices independently of the competition intensity (or the number of bidders) for a project.

Measuring market conditions

No definitive measure for market conditions in construction exists in the literature. It is suggested that, in these circumstances, the standard approach is to identify a measurable quantity that can be taken as an indicator, or proxy for the variable we are actually trying to measure (Flanagan *et. al.* 1983). These proxy variables' values, and changes in values, constitute an indirect measure of the variable we are trying to measure. In this sense, many possible proxy variables for market conditions can be envisaged. McCaffer *et. al.* (1983) used the ratio tender price index to construction cost index to represent prices changes due to market conditions. Flanagan *et. al.* (1983) used number of bidders received for particular projects as a manifestation of market conditions. They further suggested that the rate of change of a price index (such as Tender Price Index) would be a more appropriate proxy variable for market conditions. Runeson (1990) derived

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an economic conditions index based on average of all tenders' markup in an attempt to incorporate market conditions into tendering models.

Because of data limitations, as in our case, there is no formal compilation of either a market condition index or building cost index in Hong Kong. For the purpose of this empirical study, we shall take the rate of change of tender price index TPI (hereafter denoted as TPI_r) as an indirect measure of market conditions. In Hong Kong, TPI is generally compiled by comparing the prices of a proportion of the items within a number of successful tenders during a given period against the price of similar items in a base schedule of rates (Chau 1998). It represents the cost a client must pay for a building. It includes all input prices and takes into account the prevailing market conditions. The movements of tender prices and input prices are monitored by tender price and building cost indices respectively and one of the major uses of TPI is for forecasting tender price level (Tysoe, 1981).

Empirical Analysis (I): Minimum number of bidders

As stated above, we shall use TPI_r (i.e. rate of change of TPI) as an indirect measure of market conditions. Besides, we shall use 1/N as a measure of the degree of competition (since the number of potential competitors also depends on type of project and geographical location, the average number of bidders per project N is used) and examine the relationship between market conditions and the degree of competitiveness for each project in Hong Kong data set. In order to develop a regression model for 1/N using the TPI_r as predictor, there are basically three steps involved.

The first step is to use a polynomial to model the time series of TPI over a period of time. By using "time, t" as predictor in a polynomial regression analysis of TPI, we shall construct a best model of a polynomial of degree n as shown in Equation (1) below that provides a very good fit to the TPI.

$$TPI = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 + ... + \alpha_n t^n \qquad (1)$$

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Once the model of the time series of TPI is constructed, the second step is to differentiate the polynomial with respective to time t as shown in Equation (2) below. By substituting different values of t into Equation (2), TPI_r values can be obtained for different values of t.

$$TPI_r = \alpha_1 + 2\alpha_2 t + 3\alpha_3 t^2 + \ldots + n\alpha_n t^{n-1} \qquad (2)$$

When TPI_r values are found, the third step is to work out the ordered pairs of (1/N, TPI_r) for the time period. Then a regression model for 1/N using the TPI_r as predictor can be constructed as shown in Equation (3) below. Thus, based on this approach, we can estimate the average number of potential bidders N in the market for further analysis. Since TPI is a time series, inferential time series regression or autoregressive models can be constructed to forecast the TPI level in the industry. While there is a key advantage of regression analysis over other smoothing forecasting techniques (i.e. it provides a measure of reliability of each forecast through prediction intervals), it is generally risky for prediction outside the range of the observed data that may make the model (i.e. Equation (1)) inappropriate for predicting a future TPI level. Therefore, it is suggested that the forecasting of a TPI level in the industry is generally confined to the short run.

$$\frac{1}{N} = \beta_0 + \beta_1 \times TPI_r + \beta_2 \times \left(TPI_r\right)^2 + \ldots \qquad (3)$$

One major problem facing construction clients, particularly the HKSAR Government, is how to obtain competitive bids for their projects in a cost effective way and at the same time maintain its public accountability. Traditionally, construction clients, at least for the HKSAR Government, encourage large numbers of contractors to submit bids for each project. Drew and Skitmore (1990, 1992) have shown from their sample data set taken from Hong Kong's private and public sectors that tendering competitions average from 10 to 17 contractors respectively. Several empirical studies have shown that greater number of bidders in competition for each project reduce the value of the lowest bid (Skitmore, 2001). However, there has been quite a body of literature concerning the issue of limiting number of potential bidders and bid preparation costs in competitive tendering (eg., Engelbrecht-Wiggans 1980; Skitmore, 1981; Scheizer *et. al.* 1983; Samuelson 1985; Flanagan *et. al.* 1985; Wilson *et. al.* 1987; Wilson *et. al.* 1988; De Neufville *et al.* 1991; Holt *et. al.* 1994, Remer *et. al.* 2000). The key idea is that a large number of contractors in tendering competition will increase procurement costs. It is a waste of limited resources when there are many competitors in tendering competition for projects in the market, for instance, during the period of lower demand level in the industry, while only the lowest bidder will win the project. The high proportion of wasted resources as a result of abortive tendering may offset any potential savings obtained from the lowest bid-win tender. Therefore, policies of limiting the number of bidders in competition would be beneficial to the industry as a whole.

Some research findings recommend restricting competition to between four to eight contractors for each project (Scheizer *et. al.* 1983; Flanagan *et. al.* 1985; Wilson *et. al.* 1988; De Neufville *et. al.* 1991). The main argument for this approach is that a higher number of contractors in competition only has marginal impact on the value of the lowest bid received. Another approach suggests that there exists an optimum number of competitors for each construction project. This approach is based on the assumption that (1) there is a quantifiable cost of tendering from the competitors associated with every bid; (2) the total cost of tendering increases in proportion to the number of competitors; and (3) potential savings diminish with increasing numbers of competitors. The argument for this approach is that ultimately this cost of tendering must be recovered from clients in the long run.

Which approach to adopt poses one fundamental question: why do tenders vary? Only by answering this question can a well-founded theoretical basis for further progressive thinking be formulated. For this, Runeson and Raftery (1998) have given a comprehensive account of assessing the variations between tenders. They suggest that the neo-classical micro-economic theory provides an explanation of the variations in tenders that is consistent with the available empirical evidence. If their argument is right, then the above approaches fail to explain the fundamental question properly because they are based on the basic assumptions either implicitly or explicitly: 1) tendering is a random process and 2) there is a direct cost of tendering. There are serious conceptual problems concerning these approaches. Firstly, based on neo-classical micro-economic theory, more tenders would not necessarily guarantee a lower price because price determination is actually based on interaction of demand and supply. Firms that are most desperate for jobs would also be the firms most likely to tender and thus the number of bidders is not likely have much effect on the price.

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Secondly, even if it is assumed that more tenders result in lower price and there is a direct cost of tendering, the reduction in cost is for the individual project, but the increase in cost of tendering is an industry wide increase. A little reflection shows that two such different concepts cannot simply be combined and added together. Moreover, if it is assumed that the cost of tendering is a fixed cost, then the arguments for these approaches fail to stand as well. For instance, if it is assumed that there are 10 firms each with an estimating department set up to produce 20 estimates per year, then there are 200 estimates per year for the market. If it is assumed further that one year there are 100 new projects coming on the market, while the next year there are only 20 new projects, the cost of tendering has not changed for the industry or the firm but the average number of estimates per project has increased from 2 to 10.

Instead of the above approaches evaluated, another approach will be suggested based on micro-economic theory for construction price determination in tendering. ***This assumes all bidders to be equally competitive.*** This leads to variations in tenders received, with the selection of contractors to submit tenders being assumed to be random for the purposes of of public accountability. Of course, auxiliary assumptions can be formulated in such a way that this does not necessarily follow. (?? WHAT DOES THIS MEAN??)

If the random selection of equally competitive contractors assumption is adopted, then the problem of predicting the lowest tender is non-deterministic. Skitmore (1981) assumed a random contractor-selection process in tendering to predict tender prices. He used an example in which samples of six bidders to submit tenders were selected from a population of 20 potential bidders. He then worked out the frequency distribution of the bidders' success from all possible combinations of six bidders. From this example he showed that random selection of bidders reduces the predictability of the lowest tender by reducing the chances of including potentially low tenders, while increasing the number of bidders in competition will increase predictability. In other words, it is impossible to predict the lowest tender with certainty. The best that can be achieved is to predict a range of values where the lowest tender is expected to land. Following Skitmore's (1981) example, instead of grouping a population of 20 potential bidders into ascending order of potential values, N potential bids will be arranged in ascending order of tender prices and numbered X accordingly.

After determining the average number of potential bidders N in the market from the set of equations (1-3), suppose that these N potential bidders in the market are on the approved list and they would have estimated their potential tender prices if they were asked to submit tenders for this project.

$$X = \{1, 2, 3, \ldots, N \quad \textit{where potential bid is ranked } X^{th} \textit{ lowest in the group of } N \textit{ tenders.}\}$$

From these N potential contractors, k contractors will be selected at random to submit their tenders. Then total number of possible competitions for this project can be calculated by Equation 4 as shown below:

$$\textit{Total number of possible competitions for this project} = \binom{N}{k} \qquad (4)$$

The probability of *Xth lowest bid in N bids is the lowest bid in competition* is given by the probability density function $f_{(N,\ k)}(x)$ when randomly selecting k contractors from the group of N potential contractors:

$$f_{(N,\ k)}(x) = \frac{\binom{N-x}{k-1}}{\binom{N}{k}} \qquad \textit{where} \quad x = 1,\ 2,\ \ldots\ N - k + 1 \qquad (5)$$

The simplest way to identify the lowest bid (i.e. $X = 1$) from the group of N potential contractors is to ask all of them to submit their tenders. However, as mentioned before, this would not be cost effective. Therefore, the most important question now becomes: how can the chance of including the most competitive bids be maximized, by randomly selecting k number of contractors in competition for this project once the average number of potential contractors N competing for this project in the market is estimated? While there is no theoretical definition for the meanings of maximizing the chance and the most competitive bids, for simplicity and practicality, maximizing the chance will be taken at the 95% confidence level and the most competitive bids refer to one of the first four lowest bids among the N potential competitors. In other words, there exists an 'optimum' value of k for each N such that a 95% confidence level of including one of the first four lowest bids in competition for this project can be obtained. Based on this criterion, the minimum number of contractors to submit tenders for projects will depend on the potential number of bidders N in the market that in turn will depend on the market conditions.

Suppose it is estimated that the average number of competitors (N) in the market for a particular project is 20 based on market conditions from the set of equations (1-3). A probability density function for randomly selecting the k number of bidders per project to submit bids can be established. The probability and cumulative probability distribution values of winning tenders for selecting k contractors from $N = 20$ potential competitors in the market is shown in Table 1. The cumulative probability distributions as shown in Figure 1 indicate that the k values affect the range of lowest bids received. As k value increases from 3 to 10, the range of potential lowest bids in competitions reduces from the lowest possible eighteenth bid in N bids received to the lowest possible tenth bid in N bids received. Therefore, it is desirable, at least from the client's viewpoint, that those lowest potential bids in N bids will have higher chances of being included in tendering competitions while those higher potential bids in N bids will be excluded from the tendering process. The winning tender will fall within a range of values depending on the choice of k. However, in order to include the one of the first four lowest bidders in competition for projects at 95% confidence level, the minimum number of contractors to submit tenders is when $k = 10$ giving the cumulative probability of 0.9567.

From the foregoing empirical analysis, a theoretical framework for determining the minimum number of competitors to be included in construction bidding competitions for projects has been proposed. The following empirical analysis on a HKSAR Government data set will set out to test the applicability of the framework.

Empirical analysis (II): Hong Kong Data Set

The following empirical analysis is based on a sample of 229 projects with 3,285 bids received over the period from the fourth quarter of 1990 to the third quarter of 1996. The sample was derived from HKSAR Government Architectural Services Department (ASD). Projects awarded through selective tendering (where the number of competitors is an administrative decision rather than a consequence of market conditions) have been excluded for homogeneity purposes. Figure 2 shows the positively skewed frequency distribution of number of bidders per project for the data set. On average, there are 14 contractors, ranging from 3 to 33 with standard deviation of about 7, competing for each contract.

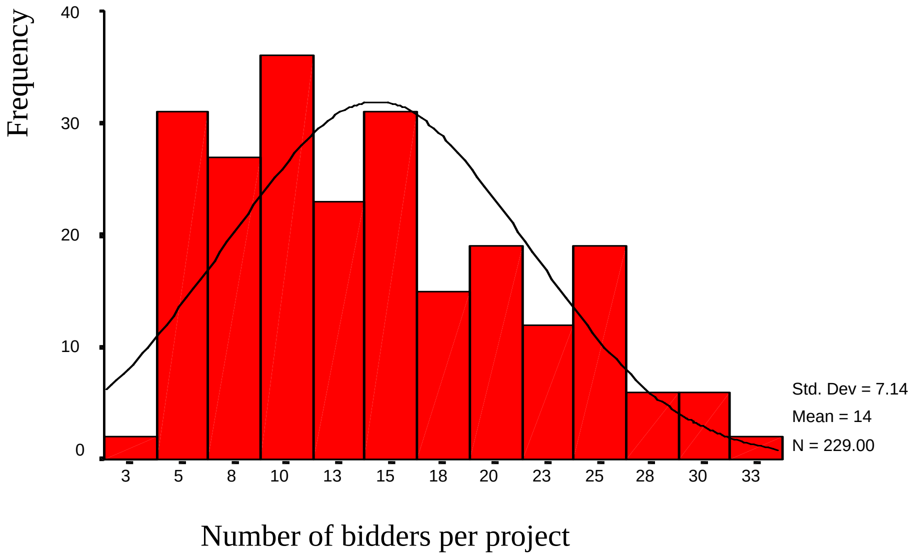

Figure 2. Distribution of number of bidders for ASD projects (1990 – 1996)

Table 2 shows the variations in TPI level and the average number of contractors per project N for the data set. The TPI used is a quarterly index compiled by ASD primarily as an aid to adjust building cost data for estimating purposes. It is prepared also to provide an indication of the price level of tender prices for new building works undertaken by ASD.

The best model (i.e. using time t as predictor in a polynomial regression analysis of TPI) is found to be a polynomial of degree 3 as shown below. This polynomial, as shown in Figure 3, provides a very good fit to the TPI as the corresponding R-square is 0.9773 and the residual plot exhibits no special pattern for violation of regression assumptions.

$$TPI = 695.617 - 37.624t + 2.893t^2 - 0.0419t^3 \qquad (R^2 = 0.9773)$$

Hence, the rate of change TPI_r at time = t is given by the following equation:

$$TPI_r = -37.624 + 5.786t - 0.1257t^2$$

By substituting different values of t into the above equation, 24 ordered pairs of (1/N, TPI_r) can be found as shown in Table 3 and the scatter plot of these 24 ordered pairs is produced as shown in Figure 4. The plot shows a non-linear relationship between 1/N and TPI_r. A regression model can be established to best fit the set of data with the following result: $R^2 = 0.7550$ and F = 32.36 (p-value < 0.0001):

$$\frac{1}{N} = 0.04843 + 0.0007134 \times TPI_r + 0.00003809 TPI_r^{\,2} \qquad (R^2 = 0.7550)$$

Suppose the forecast of TPI_r (i.e. the rate of change of TPI) is 23, then from the above regression model, the estimated potential number of competitors for a project is N = 12. The probability density function values for randomly selecting the k number of bidders per project to submit bids is as shown in Table 4. At 95% confidence level to include at least one of the first four lowest bidders among 12 potential competitors in competition, the minimum number of contractors to submit tenders is when k = 6 giving cumulative probability of 0.9697.

Therefore, by randomly selecting six contractors from the approved list qualified contractors to submit tenders to compete for a project in this period, the HKSAR Government can have a 95% confidence that at least one of the first four lowest bids in the market will be included in competition for projects. In this way, not only will this approach be more cost effective in terms of procurement costs, but also the Government can still maintain its public accountability in the tendering competitions.

Conclusions

This paper sets out to explore and demonstrate a theoretical linkage between the market conditions and number of potential contractors in competition. Based on neo-classical micro-economic theory for construction price determination and the assumption of random selection of equally competitive contractors in the bidding competitions, a theoretical framework for determining the minimum number of competitors in the tendering process is proposed. The framework comprises two basic parts. The first part applies micro-economic theory in linking changes in demand to changes in prices and subsequent changes in supply capacity to explain construction price determination and tender variations. The rate of change of TPI is used to measure market conditions in the building industry and the degree of competition can be measured in terms of number of potential competitors in the market. From these, a set of regression models is formulated to estimate the number of potential contractors competing in the market by the forecast TPI level. The second part determines the minimum number of contractors to submit tenders for the particular projects concerned such that a 95% confidence (STEPHEN – WHAT HAPPENS IF A DIFFERENT % LEVEL IS NEEDED? CAN WE DRAW A GRAPH SHOWING THE RESULTS FOR EACH % VALUE INSTEAD OF JUST 95%??) can be achieved that one of the first four lowest bids in market will be included in bidding competitions.

The implication is that the HKSAR Government can derive a more cost effective approach in its open tendering system by selecting the minimum number of contractors k in bidding competitions based on the market conditions (or the TPI_r value) while maintaining its public accountability for contractor-selection in tendering. The limitations for this framework are 1) the prediction of TPI is generally confined to the short term because of less accuracy of forecasts farther into the future and hence may make the TPI forecasting model inappropriate; and 2) the framework is based on the assumption that contractors are equally competitive and the contractor-selection process is random. It remains possible that the selection of contractors in competition for particular projects will not be simply a random choice that reduces the range of lowest tenders. Further research is necessary to quantify the opportunity costs involved.

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X	$f_{(20,\ 3)}(x)$	$\Sigma f_{(20,\ 3)}(x)$	$f_{(20,\ 5)}(x)$	$\Sigma f_{(20,\ 5)}(x)$	$f_{(20,\ 10)}(x)$	$\Sigma f_{(20,\ 10)}(x)$
1	0.1500	0.1500	0.2500	0.2500	0.5000	0.5000
2	0.1342	0.2842	0.1974	0.4474	0.2632	0.7632
3	0.1193	0.4035	0.1535	0.6009	0.1316	0.8947
4	0.1053	0.5088	0.1174	0.7183	0.0619	0.9567
5	0.0921	0.6009	0.0880	0.8063	0.0271	0.9837
6	0.0798	0.6807	0.0646	0.8709	0.0108	0.9946
7	0.0684	0.7491	0.0461	0.9170	0.0039	0.9985
8	0.0579	0.8070	0.0319	0.9489	0.0012	0.9996
9	0.0482	0.8553	0.0213	0.9702	0.0003	0.9999
10	0.0395	0.8947	0.0135	0.9837	0.0001	1.0000
11	0.0316	0.9263	0.0081	0.9919	0.0000	1.0000
12	0.0246	0.9509	0.0045	0.9964	0.0000	1.0000
13	0.0184	0.9693	0.0023	0.9986	0.0000	1.0000
14	0.0132	0.9825	0.0010	0.9996	0.0000	1.0000
15	0.0088	0.9912	0.0003	0.9999	0.0000	1.0000
16	0.0053	0.9965	0.0001	1.0000	0.0000	1.0000
17	0.0026	0.9991	0.0000	1.0000	0.0000	1.0000
18	0.0009	1.0000	0.0000	1.0000	0.0000	1.0000
19	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
20	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Table 1: Probability and cumulative probability distribution values of winning tenders for $N = 20$

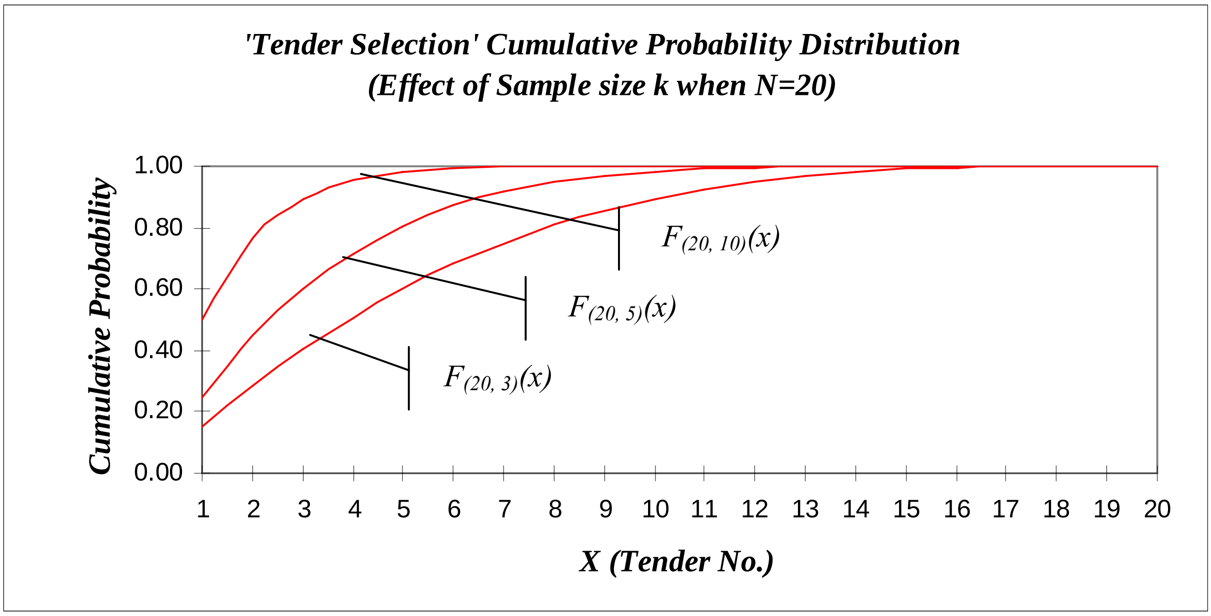

Figure 1. Cumulative probability distribution values of winning tenders for $N = 20$

Year	Quarter	Time t	TPI	No. of projects	Total number of bidders	Av. No. of bidders / project (N)
1990	4	1	596	8	112	14
1991	1	2	608	6	116	19
	2	3	592	5	119	24
	3	4	573	9	204	23
	4	5	515	8	189	24
1992	1	6	531	10	189	19
	2	7	548	6	129	22
	3	8	519	6	99	17
	4	9	518	8	148	19
1993	1	10	527	10	158	16
	2	11	527	4	61	15
	3	12	541	7	98	14
	4	13	563	5	100	20
1994	1	14	586	14	239	17
	2	15	594	7	81	12
	3	16	615	14	210	15
	4	17	666	9	98	11
1995	1	18	708	14	171	12
	2	19	712	11	110	10
	3	20	733	17	142	8
	4	21	747	13	123	9
1996	1	22	772	14	157	11
	2	23	813	10	121	12
	3	24	848	14	111	8
			Total	*229*	*3,285*	

Table 2: Variations of TPI and Average Number of bidders N (1990 - 1996)

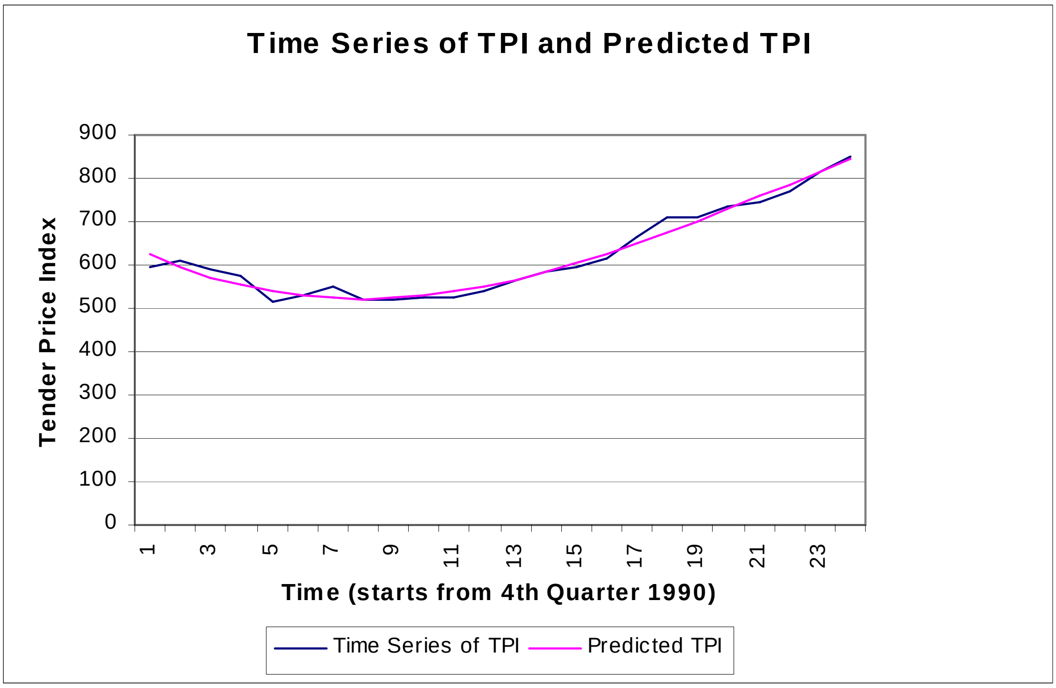

Figure 3. Polynomial regression analysis of TPI using time t as predictor

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Year	Quarter	Time t	TPI	TPI_r	Av. No. of bidders / project (N)	1/N
1990	4	1	596	-31.9637	14	0.0714
1991	1	2	608	-26.5548	19	0.0517
	2	3	592	-21.3973	24	0.0420
	3	4	573	-16.4912	23	0.0441
	4	5	515	-11.8365	24	0.0423
1992	1	6	531	-7.4332	19	0.0529
	2	7	548	-3.2813	22	0.0465
	3	8	519	0.6192	17	0.0606
	4	9	518	4.2683	19	0.0541
1993	1	10	527	7.6660	16	0.0633
	2	11	527	10.8123	15	0.0656
	3	12	541	13.7072	14	0.0714
	4	13	563	16.3507	20	0.0500
1994	1	14	586	18.7428	17	0.0586
	2	15	594	20.8835	12	0.0864
	3	16	615	22.7728	15	0.0664
	4	17	666	24.4107	11	0.0918
1995	1	18	708	25.7972	12	0.0819
	2	19	712	26.9323	10	0.1000
	3	20	733	27.8160	8	0.1197
	4	21	747	28.4483	9	0.1057
1996	1	22	772	28.8292	11	0.0892
	2	23	813	28.9587	12	0.0826
	3	24	848	28.8368	8	0.1261

Table 3: Variations of TPI_r and 1/N (1990 - 1996)

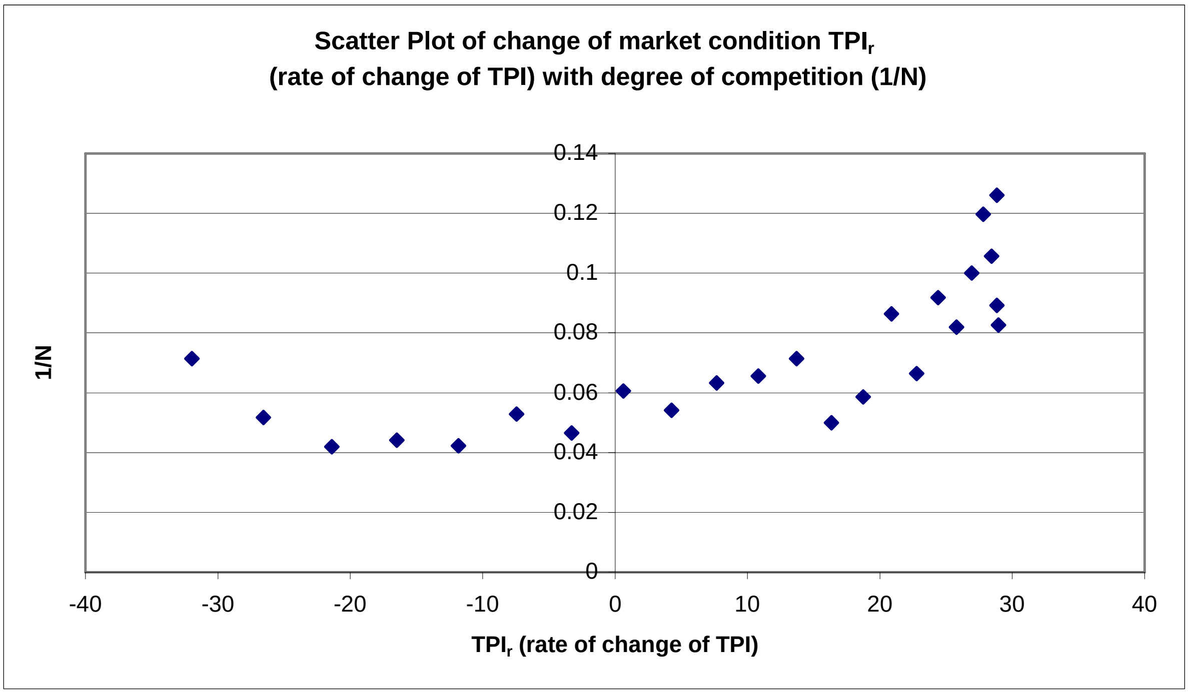

Figure 4: Scatter plot of TPI_r and 1/N

X	$f_{(12,4)}(x)$	$\Sigma f_{(12,4)}(x)$	$f_{(12,5)}(x)$	$\Sigma f_{(12,5)}(x)$	$f_{(12,6)}(x)$	$\Sigma f_{(12,6)}(x)$
1	0.3333	0.3333	0.4167	0.4167	0.5000	0.5000
2	0.2424	0.5758	0.2652	0.6818	0.2727	0.7727
3	0.1697	0.7455	0.1591	0.8409	0.1364	0.9091
4	0.1131	0.8586	0.0884	0.9293	0.0606	0.9697
5	0.0707	0.9293	0.0442	0.9735	0.0227	0.9924
6	0.0404	0.9697	0.0189	0.9924	0.0065	0.9989
7	0.0202	0.9899	0.0063	0.9987	0.0011	1.0000
8	0.0081	0.9980	0.0013	1.0000	0.0000	1.0000
9	0.0020	1.0000	0.0000	1.0000	0.0000	1.0000
10	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
11	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
12	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Table 4: Probability and cumulative probability distribution values of winning tenders for $N = 12$

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