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TENDERING THEORY REVISITED

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ABSTRACT

This paper discusses the content, origin and development of Tendering Theory as a theory of price determination. It demonstrates how tendering theory determines market prices and how it is different from game and decision theories, and that in the tendering process, with non-cooperative, simultaneous, single sealed bids with individual private valuations, extensive public information, a large number of bidders and a long sequence of tendering occasions, there develops a competitive equilibrium.

The development of a competitive equilibrium means that the concept of the tender as the sum of a valuation and a strategy, which is at the core of tendering theory, cannot be supported and that there are serious empirical, theoretical and methodological inconsistencies in the theory.

KEYWORDS: Tendering Theory, Competitive Tendering, Price Determination

INTRODUCTION

In 1956, ostensibly in the spirit of game theory, a paper by Lawrence Friedman and titled *A Competitive-Bidding Strategy* appeared in the journal Operations Research. The real importance of the paper was not so much in what it said, but in the way it generated interest, research, theorising and publications to the extent that we can now identify tendering as one of the best documented and well researched areas of building economics, although the development of a consistent theoretical framework has been slower and very little of the writings has been devoted to testing, verifying or analysing the theory itself.

Friedman's paper (1956, 1957) had a simple and clear message: to maximise the expected profit from a single tender where each competitor simultaneously submits one closed bid (tender). The bidder (tenderer) should select the mark-up on cost that maximises expected value of the profit which is the product of the mark-up and the probability of winning the contract.

As Friedman (1956, 1957) pointed out, the problem lies in determining the probability of winning as a function of the mark-up. His solution was to study previous encounters with the competitors to establish their "bidding patterns". More specifically, this is done by calculating the ratios between the competitors' tenders and the decision-maker's own cost estimate. Provided there have been a sufficient number of previous encounters, it is then possible from this pattern, to estimate the probabilities of winning with different mark-ups against each competitor and through aggregation, against each possible combination of competitors.

The rest of the paper is devoted to alternative objectives, estimating the probability distribution of number of competitors, the likely shapes of the probability density functions of the competitors' bids and the strategy when several bids are submitted simultaneously and there are restrictions on the total value of all bids. The paper is clear, every assumption is clearly stated, it is simple and deals with a simple issue: how to approach a single bid (or set of simultaneous single bids).

The next major paper on the topic was Gates' (1967) *Bidding Strategies and Probabilities*. This paper reinterpreted Friedman's strategy for a single bid into a general, profit maximising pricing model for tendering. While Gates gives no acknowledgment to Friedman's paper in the development of his own model[1], there are many similarities between the two papers. Like Friedman, Gates asserted that the probability of winning a bid could be estimated from previous encounters and that the appropriate strategy was to maximise the expected value of the profit of the bid. However, what for Friedman was the appropriate strategy for a single bid, Gates turns into *a general strategy, with general applicability.* In effect, Gates has taken a simple decision support model and reformulated it into an economic model for price determination of construction projects.

There were additional differences, including a difference in how the probability of winning over more than one competitor was estimated. In the literature, the attention has concentrated on this single aspect of the two papers and there has been a number of empirical and theoretical tests of the comparative appropriateness of the proposed methods of aggregation of probability (e.g. Rosenshine, 1972, Dixie, 1974, Fuerst, 1975, 1976, 1977, 1979, Gates, 1970, 1976b, 1979, Benjamin and Meador, 1979, Carr, 1982, 1987a), the correct analysis being applied by Weverberg (1978). The important implications of the transformation from a strategy for a single event in Friedman's paper to a general theory of price determination of construction projects in Gates' paper has, however, been completely ignored to date.

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[1] There is one oblique reference to the book in which the 1957 version of Friedman's paper appeared, where Gates remarks that "other investigators [sic] consider the problem of winning over several competitors as one of independent events" (p 102).

TENDERING THEORY AS A THEORY OF PRICE DETERMINATION

Before progressing any further, it may be worthwhile to summarise the essential characteristics of tendering theory. As expressed by Gates - and also as explicitly stated by Friedman - tendering theory is a theory of pricing. As a theory of pricing, the optimum bid has two components: the estimated cost of executing the project, including the return to capital, and a strategy for maximising profit, which, with some qualifications discussed below, is effectively a constant mark-up.

As suggested by Archibald (1959), the assumptions of economic theories can be divided into (i) statements about motivation; (ii) statements about the behaviour of the economic agents; (iii) statements about the existence and stability of functional relationships; (iv) restrictions on the range of variables to be taken into consideration and (v) boundary conditions under which the theory is held to apply. These assumptions are summarised in Table 1 below.

MOTIVATIONAL ASSUMPTION: Profit maximisation
BEHAVIOURAL ASSUMPTION: Maximise Expected Value of each tender
FUNCTIONAL RELATIONSHIPS: Constant distribution of competing tenders can be determined from previous encounters. Tender is cost plus a mark-up based on maximising expected value
RESTRICTIONS ON RANGE OF VARIABLES: No restrictions
BOUNDARY CONDITIONS: Competitive tendering only

Table 1 Summary of assumptions for tendering theory. The assumptions of economic theories may be divided into Motivational Assumptions, Behavioural Assumptions, Assumptions about Functional Relationships, Assumptions about Restrictions on the Range of Variables and Assumptions of Boundary Conditions or Applicability.

This stresses a concept of tendering that departs from the traditional way of looking at the tendering process: it goes beyond the winning tender as determining the price of an individual contract into a theory of pricing in an industry where each object is unique.

To justify the concept of an economic price theory, we need to establish that there is a market and a single product for sale in that market. Here we have a conceptual problem in the traditional way of looking at the output of the building industry. Certainly, if we look at each project as a design, a location, a time and a set of building materials, each project is unique. However, we must look away from the obvious differences in different buildings and realise that these buildings are not what the builders are selling. Builders are selling the skills to assemble buildings, the management skills necessary to combine manpower, machinery and material into new buildings.

We have different markets because the skills required for different types of projects are different. On the other hand we have distinct markets for each type of projects. There is for instance virtually no difference between the skills required to construct different single family dwellings and any participant in that market can produce any of the products traded within that market. The same is true also for the market for driveways or market for high rise office blocks. The building industry is selling services, and within each market, the services being sold are virtually identical.

If we have an identical product for sale and a tendering process that communicates to the buyer who is willing to sell and for what price, we have a market and a market price, and a theory that determines how that price is derived is a theory of pricing, even if the product is traded in bundles of different sizes each time.

CONSTANT MARK-UP

The second characteristic of the pricing model as presented by Gates is that the strategy for maximising profit is a mark-up that is constant, over time and in practice, from tender to tender. This is another crucial difference between on the one hand Friedman’s concept of a strategy for a single tender and on the other hand, Gates’ general theory of tendering as well as extension of Friedman’s model (e.g. Park, 1962, 1963, 1964, 1966, Park and Chapin, 1992). Friedman assumes, for the purpose of estimation, "that each competitor is likely to bid as he has done in the past" (p 107), a *ceteris paribus* condition that may not necessarily be an actual representation of reality, but may be sufficiently close to convey a competitive advantage to the user.

Gates, being less clear, does not state the assumptions explicitly, but uses empirical data derived over a period of several years to establish the probability of success, and a technique which explicitly excludes the possibilities of systematic changes in the mark-up as a correspondence rule for calculating the probabilities of success at different mark-ups. After having calculated the optimum mark-up for competition with firms A, B and C, Gates states that this optimum mark-up is constant over time, because this is "*the best mark-up to include whenever your competitors are only A, B and C*" (p 86, emphasis added. There is no need to re-estimate the probability density functions at any stage or for any reason. This statement specifically excludes the possibility of systematic variations in the mark-up.

The fact that probabilities are being assigned to the bids at all assumes that bids occur in a manner amenable to statistical treatment. This implies that bids are fundamentally random in nature, drawn from an underlying probability density function with fixed parameters. To estimate the value of these parameters empirically for construction contract bidding inevitably involves making assumptions about the stability of these parameters over time as observations (bid values) of a sufficient number are simply not available at a single point in time. Indeed it has even been argued that sufficient numbers of observations cannot be available over even over time (Curtis and Maines, 1973).

This raises a vital issue of theoretical relevance. Firstly, as the empirical demands of parameter estimation involves the **practical** assumption that bid pdfs do not change over time, it can be argued that it logically follows that the same assumption is implied **theoretically**. To accept this argument also means accepting that all practical behaviour has implied theoretical bases. This is a pivotal issue with deep philosophical traditions and means, for instance, rejecting the notion of atheoretical behaviour as absurd. Current work on the philosophical basis of general economic theories (e.g. Blaug, 19??), however, overwhelmingly supports the acceptance the implied theory argument. Economic theory is built entirely on that which is implied from practice and therefore without implied theory there can be no economic theory.

Similarly, the tendering theory that is implied by Gates holds that market conditions or the competitors' capacity utilisations in themselves do not influence the behaviour of any of the competitors in any systematic way as his very use of statistical models assumes that all variations in tenders conveniently originate from unsystematic or random variations in the competitors' and/or own cost estimates and/or mark-ups.

It follows, therefore, that, if systematic changes in bidding behaviour do occur in reality, as for instance in different markets or in response to changes in demand, the theory cannot hold, for the mark-ups can no longer be regarded as random. There are also consequences in practice too[2]. A further

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[2] Cf for instance a set of temperature records from different Australian weather stations covering all seasons. This is a frequency distribution and also a probability distribution for a temperature reading at a random weather station at a random time. However, it is not a good predictor for a temperature reading at a specified location at a specified time such as Darwin on New Year's Eve or Snowy Mountains in mid winter. In the same way, the records on mark-ups from different markets and different market conditions are not good indicators of the relevant mark-ups for a specific project in a specified market and in a specified set of market conditions. Mark-ups established when the market is overheated are not valid when

difficulty, common in many areas of economic theory, is that, paradoxically, the mere application of the prescriptions derived from the theory is sufficient to undermine the theory from which they have been derived. In this case, the assumption that the competitors do not modify their behaviour at any time in response to the use of the strategy as developed by Gates is unlikely to be correct if Gates' strategy is of value. This, as indicated below, is a crucial difference between tendering theory and game theory.

In terms of using the calculated probability density functions, Gates starts with the situation where the competitors and their probability density functions are known, but extends the analysis to situations where the competitors are not known but are assumed to be "typical bidders": an average of bidders encountered in the past. Under these conditions, the optimum mark-up would remain constant for the typical case with **n** typical competitors. The probability density function would change only in response to changes in the number of competitors or to the presence of specific competitors. If, on the other hand, any of these conditions is violated, the probability distribution for each tender process would be unique, hence the optimum mark-up would also be unique for each tender process.

For each tender, the tender price is set by the cost estimate plus a constant percentage-mark-up. For obvious reasons, the bidder will not always be successful. After all, the bidder is aiming only for a predetermined fraction of the contracts, and the accuracy (or rather lack of accuracy) of the bidder’s own and the competitors’ cost estimates of their, as yet unknown, future costs will ensure that there are no certainties. However, if the probability density function parameters can be accurately assessed and the cost estimates are closely distributed, the winning bid will be close to the own bid. The price, which for each contract is set by the winning tender, is based on the cost plus a mark-up from a given probability density function. The bids will vary somewhat between different bidders because the uncertainties in assessing in advance, the extent of services required, but within narrow limits, the probabilities of winning with any price will be constant. This will be the case across the market, and differences in the prices offered between different bidders and projects will reflect random differences alone. It then follows that all bidders, if they all behave rationally in accordance with tendering theory, will apply a given mark-up consistent with the number of competing bidders, and any differences in bids will be the result of differences in the original cost estimate.

Tendering theory as implied in Gates' strategy is a theory that assumes constant mark-ups unaffected by variations in demand. The price is calculated as costs plus a constant mark-up, and

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demand is low and the competition intense.

potential activities and counter-strategies of competitors are assumed away. To the extent that there are any differences between different competitors, these arise from the necessity to estimate the cost prior to the execution of the contract and any aberrations caused by the process of submitting a single, unchangeable bid rather than the more conventional method of pricing the product when the cost is known.

DIFFERENCES BETWEEN GAME THEORY AND TENDERING THEORY

Before progressing further, it is appropriate to discuss the validity of the claim, implicit in the use of maximising strategies and probabilities and in the references to game theory and von Neumann's and Morgenstern's theoretical work, that tendering theory is based on game theory.

Game theory is the analysis of problems involving the interactions of rational agents. In a zero sum game such as tendering, where the winner takes all, this requires the assumption that the competitors adopt the most profitable counter strategy, and the selection of the "best" defensive measures (Kohler, 1982). Similarly, Shubik (1955) argues that game theory applies when

> the outcome of the behaviour of firms and individuals does not depend on their own actions alone nor those combined by chance, but also on the actions of others who sometimes oppose, sometimes fortify, those of the former (p viii).

The basic assumption in game theory is that the pay-off depends on the strategy selected by that player and the strategy selected by the other players (Bomoul, 1977, p 427). This "Conscious Conflict" is an absolute requirement for game theory to apply (Naylor and Vernon, 1969, Fudenberg and Tirole, 1989) and any predictions that are inconsistent with a presumed if vaguely specified, rationality are rejected. Game theory requires that all players consider their respective strategies and select the most appropriate strategy assuming that all other players do the same. It does not apply to a situation where one player alone is allowed to adopt a preferred strategy without any attempts from other players to modify their strategies in response. The assumption in tendering theory that there is no response, no modification of the behaviour of other players violates the most fundamental assumption of game theory.

There are also problems with game theory for the kind of complex problems tendering theory represents. Arrow (1994), discussing the fundamental concept of game theory points out that each firm depends on a conjecture of other firms' actions, but there is no reason to believe that these actions should be consistent. Schmalensee (1988) and Friedman (1956) similarly suggest that the assumption that boundedly rational humans can solve the very complex problems encountered in real life seems to push the rationality assumption very far indeed.

In addition to these problems, the predictions of game-theoretical models often seem delicate. Important qualitative features of equilibria often depend critically on whether prices or quantities are choice variables, on whether discrete or continuous time is assumed, on whether moves are sequential or simultaneous, and - perhaps most disturbing of all - on how players with incomplete information are assumed to alter their beliefs in response to events that cannot occur in equilibrium (Schmalensee, 1988). Arguments about learning taking place during games do not improve the situation. Allowing for rational learning simply requires the formulation of successive new and more complex games as behaviour changes (Axelrod, 1984).

It can also be demonstrated that if mark-up is regarded as a continuous variable and hence infinitely divisible so that it represents an infinite number of possible strategies while the-pay-off is discontinuous as in either winning or not winning, as we have in tendering theory, then there is no pure strategy equilibrium (Fudenberg and Tirole, 1989, pp 270 - 71). Hence, tendering theory cannot theoretically represent an optimum game strategy, making it absolutely clear that, despite the terminology in Gates' original paper suggesting otherwise, tendering theory cannot be classified as a game theoretical approach to pricing.

TENDERING THEORY AS DECISION THEORY

Gates (1967, p 75) referred to tendering theory as a strategy of bidding. Consequently, tendering theory is often seen as simply a prescriptive or normative theory rather than as descriptive or positive. Tendering theory, according to this argument, is no more than a model of rational behaviour, and rationality according to this argument, is a normative concept. Seen that way, tendering theory like almost all other social science theories would be normative theories, irrelevant to the explanation of actual behaviour (Rosenberg, 1994).

However, in a normative theory, the 'ought to' also implies 'being able to'. Tendering theory is not only about how tendering 'ought to' be performed, but also an explanation of achievable rationality. Rationality, whether aimed for or postulated as an axiom, is about outcomes (Elser, 1989), which if achieved, will have implications that, at least in principle, can be observed, tested and verified or falsified. Hence, the *a priori* argument that theories like tendering theory that stipulate rationality and can also be formulated in a normative way as decision rules cannot also be descriptive or positive is invalid. Such an argument must be empirically derived.

The counter argument to this view is that it is widely accepted that there are sanctions that apply for the violation of rational behaviour. Only rational behaviour has some chance of surviving in business (Alchian, 1950), or, in a more general form: irrational behaviour cannot be afforded (Becker, 1962).

A main difference between tendering theory and the theory of decision analysis (or, as it is commonly referred to, decision theory), is that the tendering theory stipulates a universal maximisation objective, while decision theory provides the analytical tools to maximise any individual utility function irrespective of what this utility function is (Keeney and Raiffa, 1976). Also in this interpretation, Gates' model is very much a positive theory of price determination.

THEORY OF AUCTIONS.

The process of obtaining new jobs through tendering with simultaneous single sealed bid tenders for unique projects prior to the actual cost being known, has so many aspects to it that there has been very little work done on the actual outcome, the price. This is where auction theories could potentially be useful.

Auction theory comes in many models designed to deal with many different situations. Auction models are distinguished by the number of bidders and/or sellers, by symmetric or asymmetric information between bidders and seller or between bidders, the information available, type of auction, type of bidding, single or sequential auctions, finite or infinite sequences, equal or individual-private valuations of the item auctioned, cooperative or non-cooperative bidding, with or without a reserve price, with or without commitment to accept the result of the auction, willingness to accept risk and so on. The empirical importance of tendering is reflected in the number of papers, articles and books devoted to various aspects of auctions. Tendering is a common method of procurement for many different types of goods and the value of goods traded through auctions or tenders is huge (Milgrom and Weber, 1982).

The type of auction applicable to tendering is the non-cooperative, simultaneous, single sealed bid type with individual-private valuations, with, if not perfect, at least extensive public information, a large number of bidders for an infinite or long sequence of auctions. The significance of a single bid auction is that the single bid is assumed to express both the private valuation of the contract and the strategy employed to achieve success (Kagel, Harstad and Levin, 1987). However, the potential distortion of including a strategy in the bid is limited. The so called Revenue-Equivalence Theorem suggests that the single sealed bid auction on average yields the same price as the English, the Dutch and the second price sealed bid auctions (Vickrey, 1961, Harris and Raviv, 1981, Holt, 1980, Reiley and Samuelson, 1981, Kagel and Levin, 1993).

Applying this to tendering in the building industry, there is one more bit of information required: what happens in repeated auctions. Auctions are one of the areas where experimental results are available, so that we have replication without the violation of any *ceteris paribus* conditions and therefore real opportunities to test the theorems. Evaluating such experimental results, Roth (1988, p 1006) comments:

> One of the striking and by now well known results from the literature is that ... it is possible to observe traders converge to competitive equilibrium, in repeated markets . . . often in relatively few periods, as traders gain experience, through repetition, with the parameters of the market.

Similarly, McAfee and McMillan (1987b) summarise that auctions serve to aggregate dispersed information and "Provided there are many bidders, and provided information is sufficiently dispersed among the bidders, the price equals the item's true value..." It is quite obvious that the tendering process as such does not inhibit the development of a competitive equilibrium price and if the term "true value" means anything in this context, it must refer to the value the item would have in a competitive equilibrium if it was traded by some other method. Indeed, auctions are the answer to Arrow's criticism that neo-classical economic theory does not provide a mechanism for the process of price adjustments. Auction theory provides an explicit model of how prices adjust to demand and supply (1959).

In summary, auction theory does not support the tendering theory with its concept of the tender as a combination of a true cost and an independent strategy for winning. As has been demonstrated above, neither can tendering theory support a game theory equilibrium.

DEVELOPMENTS IN TENDERING THEORY

The major interest in the development of tendering theory dates back to the period 1967 - when Gates published his paper - up to the early 1980's, although there are more recent-re-statements of the theory, one of the more comprehensive being *Construction Bidding: Strategic Pricing for Profit* by Park and Chapin in 1992. Most of the discussion, as suggested above, has concerned the differences in aggregation of the probabilities of being successful against other builders individually. Avoiding that problem altogether, Hanssmann and Rivett (1959), Sugrue (1980), Carr (1967, 1982, 1987a), and Seydel and Olson (1990), without changing the essential assumption of constant probability density functions, reformulated the problem to that of being successful against the lowest competitive bid only.

A number of writers have introduced basic neo-classical micro-economic concepts into the models. De Neufville, Hani and Lesage (1977), Carr (1982) and Willenbrock (1973) suggested the maximisation of expected utility rather than the maximisation of expected value, while Goodman and Burmeister (1976), Knode and Swanson (1978) introduced the possibility of capacity constraints and Carr (1987b) uses opportunity costs rather than money values. This was further developed by Seydel and Olson (1990) who constructed a more complex preference function which included risk and continuity of work as well as profit. Flanagan and Norman (1982) examined the consequences of approaching the capacity limit in terms of increases in the Marginal Cost and referred to the capacity limit as where the Marginal Cost is equal to Marginal Revenue. Gates has also proposed that there may be different markets, where the bidding strategies may be different (Gates, 1976a).

Some or all of these modifications may be justified and also quite consistent with the original tendering theory, which here has been taken to be Friedman's model, extended as a general theory by Park and others, or Gates' model. With the possible exception of Flanagan and Norman, they do not contradict the core of tendering theory: the assumption that variations in the competitors' bidding are the results of unsystematic variations of cost estimates and/or mark-ups, nor the central behavioural assumption that the preferable strategy is to maximise the expected value, in money or utility, of each bid. Certainly, none of the proposed modifications has been generally accepted. In the most recent and very comprehensive restatement of tendering theory by Park and Chapin (1992) none of these developments is incorporated, or even discussed at length.

More 'radical' reformulations have been proposed by Beeston (1982) and Grinyer and Whittaker (1973). Beeston suggest smoothing, i.e. to assign a higher weight to the most recent events and correspondingly lower to more distant events when calculating the probability density functions[3]. This is equivalent to saying that the tendering theory as implied by Gates is fundamentally flawed for determining tender prices, but if we change the correspondence rule and drop the assumption of constant probabilities, what is left, which is essentially Friedman's strategy for a single tender, can be used as a simple 'naive' forecasting model where existing trends may be

[3] A system of different weights for previous tenders had been advanced as early as 1969, by Morin and Clough. The paper, while published two years after Gates', retains some of the characteristics of Friedman's model, including the same *ceteris paribus* condition but presented as a general model of tendering as proposed by Park (1966) and Gates. The weights were to ensure that the technique could be used even if the *ceteris paribus* condition was not satisfied.

extrapolated. This translates into a slight modification of the technique for assessing the probabilities developed by Friedman, necessitated by the dropping of the *ceteris paribus* condition.

Grinyer and Whittaker suggest that, over time, there are variations in the competitiveness in the market, and that the problem can be solved by including as an additional variable 'managerial judgement'. Apart from the problem of formulating 'managerial judgement' so that it becomes a meaningful and quantifiable operational variable, it seems to be only a small step away from using managerial judgement without going to the trouble of calculating incorrect probabilities of success in advance. This modification, like Beeston's, rejects the central core of the theory without apparently noticing.

Implications for Tendering Theory as a Theory of Pricing

As suggested above, in the typical case with *n* unknown competitors, tendering theory states that the tenderer's offer comprises an estimated cost plus a constant mark-up. This offer or bid may not always win, but each time it does, the offer becomes the price (see McCaffer and Thorpe, 1991), and presumably the number of bids and the probability of winning the contract ensures an adequate work load. This is in no way different from any other sales situation where the buyer has a choice between several sellers buying only one product, implicitly rejecting the offers of all other sellers.

If *n* changes, it means that the expected value of all mark-ups will change, and hence it is likely that the optimum mark-up will also change, as, indeed it may if one or more competitors are recognised as non-typical bidders. However, the fundamental characteristic of the theory is that prices are not affected by short term changes in demand and or capacity utilisation. None of the proposed changes would affect these basic characteristics of tendering theory.

Criteria for Evaluating Theories

Although there are no generally agreed criteria for evaluating a theory, the most commonly cited requirements of theories include the ability of the theory to make accurate forecasts, high informative content of the forecasts, applicability or realism of the assumptions, consistency with the predominant paradigm and finally simplicity of the theory (Runeson, 1983). Evaluating tendering theory in some of these respects should therefore give us some indication of the relevance of the theory.

For the ability of making accurate, informative forecasts, we will now look at how tendering theory deals with the effects of a change in demand and how that compares to available empirical studies. For applicability, we will examine the assumption of randomness of bids and the assumption that tender prices are costs plus a predetermined mark-up used in tendering theory.

A CHANGE IN DEMAND

One of the characteristics of the markets for building and construction services is rapid substantial changes in effective demand. For the industry as a whole, these changes may be ten or more per cent per year, for individual markets they may be even more substantial, sometimes reaching fifty or more per cent in a year. These changes may be prolonged over several years. In NSW the mid-1983 trough in building activity represented a halving of the value of construction over the preceding peak and was followed by an increase by a factor of 2.5 over the succeeding six years (Donoghue and Munro, 1991, also Anderssen and McEvoy, 1990). It is therefore, from an informative point of view, important that a theory of pricing can effectively incorporate the effects of changes in demand.

According to tendering theory, a change in demand will not change tendering behaviour, as this would represent a systematic change in strategy, and systematic changes are excluded by assumption (Shash, 1993). Tendering theory states that the probability density functions of all known competitors and the average competitor or, alternatively, the lowest bid are constant and given. It states that tender prices will change only if costs or the composition or number of competitors change, but there is nothing in the theory to suggest that this will happen as a result of any change in demand. The mark-up (profit), for the typical case with n typical competitors is a function of n and will therefore change only if n changes.

Empirical studies have, however, shown quite conclusively that prices do change in response to changes in the level of demand, or more precisely, in conjunction with changes in the level of activity in the industry. De Neufville *et al* (1977) found that prices change with the number of competitors, as predicted by the tendering theory, but also that the price level is systematically different in what they refer to as "good" and "bad" years. Carr and Sandahl (1978) demonstrated that the tender price changes much more than does cost when the demand changes. Runeson and Bennett (1983) found systematic changes in the price level in response to changes in demand and in the utilisation of capacity in the industry, and Runeson (1988a), investigating a single market found that prices systematically changed by more than plus/minus 20 per cent over the business cycle in response to changes in the level of activity in the market, even when the number of competitors was held constant. It was estimated that 85 per cent of these price changes could be explained by changes in demand and capacity utilisation, i.e. in variables describing market conditions. The number of competitors was found to have a minor impact only, with an additional competitor reducing the tender price by only 0.7 per cent on average (Runeson, 1990).

Similarly, McCaffer, McCaffrey and Thorpe (1983) found a strong relationship between the price level and the level of competitiveness in the building industry, but their results, based on a sample drawn from several different markets, also indicate that market conditions may be quite different for different types of buildings or in different regions, indicating that the industry is indeed divided into several non-competing markets. That tender prices change in response to market conditions is clearly reflected in the use of so called Tender Price Indices that are now compiled in an increasing number of countries, sometimes with different indices for different types of construction and different regions. Sweden, for instance, publishes two residential building price (output) indices, one for medium and one for high density construction. These indices frequently move at different rates or in a different direction to input cost indices and sometimes, as in 1976 and 1984, in different directions to each other (Byggindex, 1992).

Unfortunately, price changes do not, on their own, either confirm or falsify the theory. In tendering theory, the price level as such is not an issue, as it is concerned only with mark-ups. The prices will however change if cost changes. A pragmatic way of looking at this is that in order to expand capacity, new factors of production have to be employed. These new factors are likely to be less skilled or specialised and therefore less productive than those previously employed, hence lowering the overall productivity and increasing costs. The process is symmetrical. When capacity is reduced, the less productive factors of production leave the industry and overall productivity increases and the cost level falls. The impact of this can be quite substantial. From 1950 to 1980 the annual rate in productivity growth across the construction industry in the United States ranged from - 9.3 to + 7.4 per cent per year (Weber and Lippiatt, 1983).

This should obviously have an impact through the cost estimate. In addition, if it is assumed, as did Runeson and Bennett (1983), that the average number of bids is a function of the available capacity in the industry, upturns and downturns in the level of activity will be accompanied by price changes generated by changing numbers of tenderers. The testing of the theory must therefore, at least to some extent, be concerned with the process of price formation rather than the traditional, positivist method of examining the outcome. As the process cannot be observed in the equivalent way to the outcome, this raises some doubts about the results of any testing. Motives and intentions cannot be observed or measured but only inferred.

However, some indication is given by the magnitude of the price changes reported by Runeson (1988a). If labour contributes approximately fifty per cent to the total cost of building, plus/minus twenty per cent change in the price of construction over the business cycle would require that the productivity increases by a hundred per cent from the boom to the recession, which appears excessive. It also appears that it is the process of change in the level of output that determines the price rather than, as would be expected, the absolute level of output.

The alternative assumption, that mark-ups are not constant but change in response to changes in demand, has been reported in several studies. Andrews and Brunner (1975), in one of the earliest economic studies of the building industry, found that all builders change their tendering strategy systematically in response to changes in demand. Grinyer and Whittaker, (1973), Gaver and Zimmerman (1977), Beeston (1982), Flanagan and Norman (1982, 1985), Upson (1987), Skitmore *et al* (1990), Harding (1992), Sash and Abdul-Hadid (1992) as well as a number of unpublished studies have found that market conditions are an important determinant of mark-up strategy. This is supported also by Harrison, (1981), March, (1987), and Hillebrandt and Cannon, (1990). Auxiliary support is provided by observed differences in the distribution of bids over time, as reported by Johnston (1978) and Skitmore (1986b).

It is also well documented in other industries that some of the price movements caused by rapid changes in demand is absorbed in changes in quality (Esher, 1982, Gal-Or, 1985, Powell, 1989). The same response has been reported also for the building industry (Niss, 1965, Rajab, 1981).

A major study of a firm's profit encompassing 221 projects over 28 years by Chan *et al* (1996) also found a highly significant relationship between market conditions and actual profit on individual projects. The magnitude of the differences was far greater (-26 + 35 per cent) than anything that could be attributed to different numbers of tenderers alone, and the most likely determinant was differences in mark-up strategy during different phases of the business cycle.

While tendering theory can accommodate price changes as long as they apply across the industry, it cannot allow for systematic changes in the mark-up strategy (Shash, 1993). Any measurable systematic change in behaviour by one or all competitors will not be taken into account in estimating their probability density functions parameters. Hence, it is clear from these empirical studies that tendering theory, as implied by bidding strategists, does not reflect accurately what happens in a market for building management services when demand changes. The price level in the industry is determined by the level of activity in the industry, and in the short run when capacity cannot change, the adjustment to the new market situation takes place through changes in the price level as the mark-ups of all tenderers in the market change.

THE ASSUMPTION OF RANDOM VARIATIONS IN TENDERS

As demonstrated above, it is an essential assumption of the tendering theory that the probability density function of the competitors' tenders and the own cost estimates is constant. That requires a pattern of price differences originating in random variations rather than systematic variations.

Technically, it is of course also possible that there are random variations in the cost calculations that result from subcontractors who unsystematically submit different bids to different contractors to be used in the cost estimates or if the cost estimators used different sets of subcontractors, with unsystematically different cost estimates. While it is potentially possible that this can occur, it represents a logically indefensible position to build a theory around the assumption that there is, as stipulated in the tendering theory, a cost and a constant probability density function which with several bidders lead to fairly close tenders in the case of head contractors but not subcontractors.

There is some evidence that there are informal links between head and sub contractors that are not based on price alone (Eccles, 1981, Runeson and Uher, 1984, 1986, Uher and Runeson, 1984, 1985) and of differences between the prices of different subcontractors (MBA Vic & DHC 1984, Runeson 1987, 1988b). However, there is no indication that these differences are substantial or systematic enough to account for more than at most half and probably much less of the variations in tenders normally reported with standard deviations typically of 6 - 8 per cent (e.g. Ashworth and Skitmore, c: 1983). On the contrary, Runeson and Uher (1984) found that differences in sub-contractors' tenders were based on anticipated differences in timing of payments or in work organisation and therefore reflected anticipated costs or productivity.

In the literature, there are constant references to unexplained variations in tenders. Kaka and Price (1993) suggest that due to errors, a tenderer would always arrive at different prices for the same project, Lang and Mills (1979) refer to "ever present" mistakes, Van Der Meulen and Money (1984) liken tendering to a game of darts and Gates (1977) calls it "the game of the greater fool". While these statements would seem to indicate that tendering is a "hit and miss" process, not substantially different from a lottery or a game of chance, this is not, in our experience, the attitude among the people involved in actually preparing or submitting tenders in the industry. While there is still an element of chance, the degree of uncertainty appears much less prevalent among practitioners than among academics. Part of this difference in attitude may be because tendering is not such a random process as assumed in academic literature.

There are strong indications that the variability in tenders is not primarily the result of a random process. McCaffer (1976), for instance, presents an analysis of sequences of bids from individual tenderers relative to the bids of their competitors, which shows a very clear, consistent non-random pattern. According to this analysis, the tenderers typically reduce their bids gradually, relative to their competitors when they are unsuccessful until they win a contract. However, immediately after a tenderer has been successful, the following bid increases sharply in relative terms, and a new cycle of gradual decrease starts. In the study, 84.24 per cent of winning tenders were preceded by at least two consecutive decreases in relative price, and in 65.41 per cent of the cases, there was a sequence of five or more consecutive decreases before a successful tender (p 133)[4]. Hence, in less than 16 per cent of the cases the successful tender was not preceded by a sequence of falling tender prices. This work has been duplicated for subcontractors by Yiin (1987) who found exactly the same behaviour. Using a different technique, Griffis (1992) has obtained very similar, highly significant results. *These studies strongly indicate that there is very little randomness in tendering* (see also Flanagan and Norman, 1985).

If tenders are less random than assumed, this poses two questions: (i) if tenders are known not to be competitive, why are they submitted at all; and (ii) if tenderers can estimate with a high degree of accuracy, why are there such variations in the tenders for a typical project.

The answer to the first question is quite simple. All projects are unique in terms of the quantities of building management services required. Therefore, one practicable way to obtain information about current market conditions and how they affect the price level is to complete an estimate of what is required, and see how that relates to the winning tender price. Only by participating and tendering on a continuing basis, can a tenderer keep abreast of what is happening in the market. On a more pragmatic level, contractors are also often submitting bids to show that they are still in the market. This is especially so when they have been invited to tender. Griffis (1992) and Upson (1987) report that clients often give the perception that a failure to bid will prejudice the firm in the future. One obvious and well known consequence of this is the so called "cover bid" which in a typical analysis cannot be distinguished from a genuinely competitive bid (Skitmore, 1986b).

[4] The data are for tendering to the public sector only. As most contractors would also tender for private sector contracts, it is likely that the sequences are in fact even more pronounced than these figures indicate (McCaffer, 1976, p 136).

The most likely answer to the second question is that tenderers start with a high mark-up that is systematically reduced to make the tenders more competitive as the need for a new contract becomes more urgent as described by McCaffer's cusum curve. It should be noted that this contradicts the assumptions necessary for the construction of probability density functions of competitors' bids.

Random Variations in Tenders: Summary and Conclusions

Tendering theory, with tenders based on estimated costs plus a mark-up facing the competitors' constant probability density functions, does not explain the observed distribution of tenders, but relies on various, not always very likely *ad hoc* rationalisations. In the end, it does not necessarily need to produce results that are inconsistent with the observed differences between bids or behaviour such as that demonstrated by the cusum curve. However, in order to fit observed behaviour, the central assumption of unchangeable probability density functions needs to be reformulated. The behaviour required to produce a cusum curve is conditional on a logical inconsistency in the assumptions and invalidates part of the core of the theory.

The conceptual problem with tendering theory in this context is that there is no allowance for continuity in the theory. It is not that the theory is static, it is that it is central to the theory that the outcome of one tender process is not affected by the outcome of previous events and does not affect subsequent tender processes. There is, as a consequence, no market, no price level, no change in behaviour and certainly no learning. This is presumably justified by the uniqueness of each project and the failure to consider the firm rather than the project as the appropriate unit of analysis.

Maximising Profit

The strategy for maximising profit is to maximise the expected value of every single bid. This strategy, the maximisation of the expected value of each event, is an appropriate strategy for a game of poker or betting on horses or any other game for money, where the cost of each event must be balanced against the gains and the best way of doing so is to seek the most favourable combination of probability of success and value of pay-out. The problem with tendering, from the point of view of tendering theory, is that it is not a game of odds for money. The problem is not to maximise the expected value of a set of potential tenders but *to maximise the return to a given productive capacity.* The error of logic should be apparent. The two objectives can only give the same result if there are a predetermined number of contracts that the firm must bid for, and there is no cost penalty for not reaching or exceeding the most probable work load.

This would seldom be the case. In reality there is a choice of contracts to bid for or not to bid for, and winning a contract means that part of the firm's resources is locked up for the duration of the contract so that the firm is unable to compete for potentially more profitable contracts. Losing a tender, on the other hand, may only mean that the firm can tender for any number of other contracts, but it may, in other circumstances mean that the firm's resources may be unutilised at high costs for a period of time (Niss, 1965, Mannering, 1970, Burton, 1972, South, 1979, Fellows *et al*, 1983). A numerical example should illustrate this point in an intuitive way. If we assume that the tenderer will have unutilised capacity for one project, and look at two extreme cases: (i) there is a large number of contracts to bid for, and (ii) there is only one contract to bid for, it should be obvious that maximising the expected value is not necessarily the profit maximising strategy.

If we also assume that at a mark-up of 1 per cent, the probability of winning the contract is 1.0, at 3 per cent it is 0.5 and at 10 per cent it is 0.1, tendering theory would suggest that since a mark-up of 3 per cent has the highest expected value (1.5 as compared to 1 for the alternatives), the profit maximising strategy is to use this mark-up in both cases above. However, a rational strategy for most people would probably be in the first case to submit a sufficient number of bids to obtain the desired contract with a mark-up of 10 per cent, and in the second case to submit a bid with a 1 per cent mark-up to avoid both the risk of getting no profit and the risk of paying the cost of carrying unutilised capacity.

It can similarly be demonstrated that for more typical, intermediate situations, the maximisation of the expected value of all bids will not maximise profit to the firm. A more rational strategy would be to vary the mark-up as indicated in McCaffer's cusum curve. Winning a project too early when the firm has no spare capacity necessitates a higher price as the firm must pay a cost penalty for operating above its optimum capacity and winning it too late means that it has to carry unutilised capacity (see also Eastham, 1988, and Ahmad and Minkrah, 1988). The logical fallacy of ignoring the capacity of the firm is obvious. This is where Friedman's original model has been distorted. Friedman’s model originally offered a simple conceptual model for a single or several simultaneous bids, not a strategy for sequential bidding with choice of projects to bid for. As such it represents one of several potential rational strategies.

It is difficult to construct a set of assumptions that are consistent with using the maximisation of expected value as a strategy to maximise profit. Essential assumptions are that the number of tenders is fixed, and that the capacity utilisation which results from the tendering process is irrelevant. The circumstances where the latter applies are especially difficult to specify.

THE ACCURACY OF ESTIMATES

One of the problems of following the discussion in the literature on tendering is the absence of a common terminology and the indiscriminate use of terms like "*price*" or "*cost*" to denote a range of very different concepts. The term "*accuracy*" is, even in this context, an especially misused and abused term.

It is easy to demonstrate, as Fine (1975) has done, that when there are random errors in the cost estimates on which tenders are based, the tenders will be different. However, because random errors in cost estimates will lead to unsystematic differences in tenders, it does not follow that all, or indeed any observed differences in tenders must be unsystematic and due to inaccuracies in the cost estimates, as tendering theory assumes. This particular form of logical error - if A, then B; B exist, hence A is true - is generally referred to as *affirming the consequent.*

There are two problems with taking the distribution of tenders as a measure of accuracy of cost estimating: (i) what is calculated is not accuracy - because the accuracy of cost estimates, by definition, can only be assessed in relation to actual costs - but conformity to other tenders, which is something totally different, and (ii) it is doubtful if a single event that is the result of an array of random influences that are unknown at the time of the estimate, can be said to estimated accurately or not in any meaningful sense.

The failure to assess the accuracy of tenders in terms of the actual costs is what makes it possible for Park and Chapin (1992) to state that:

> A good detailed estimate should generally be accurate within 5 per cent. Even so, on the average, *actual costs may vary by as much as 20 percent from the estimated costs* ... (p. 194, emphasis added).

which makes no sense if the purpose of an estimate is to estimate the actual cost! However, the implications of the statement are confusing not only from the point of view of the logic of the authors, but also for the logic of tendering theory. The statement certainly gives no indication that estimators are capable of estimating actual costs. In fact, since normally most tenders are grouped reasonably close together, well within the twenty per cent mentioned, it suggests that now and then, actually quite often - for some unknown reason - all estimators get it wrong by about the same magnitude and in the same direction and at the same time. This requires a behaviour that is far removed from the assumption of rationality that is central to most aspects of economic reasoning.

Park and Chapin cite no empirical study for their differences of 20 per cent, and it would be easy to dismiss the figure, were it not for the findings in a very recent study of the differences between tenders and actual cost. The study, based on all contracts for new buildings from a successful firm (n = 221) over a twenty-eight year period found that the actual accuracy was indeed very low, with the range of differences between tender plus variations and actual costs from - 26 to + 35 per cent of the tender price and a coefficient of variation of 9.58 (Chan *et al*, 1996).

However, the real problem for the applicability of tendering theory was that the distribution of profits and losses revealed in the study was systematic rather than random as would have been the case if the variations had been the result of random errors. More than two-thirds of the variations in profit/loss could be explained in terms of project characteristics that established the market, and market conditions. There is no possible way of interpreting tendering theory in such a way as to explain why a group of skilled estimators should all at the same time, so systematically and with such a high degree of conformity under- or over-estimate the actual cost of a project by as much as is required for this result.

SUMMARY AND CONCLUSIONS

In this paper we have attempted to find a place in economic theory for the voluminous work of the bidding strategists. To do this we have argued for and adopted an approach by which a theory is derived by implication through examination of the assumptions upon which the general bidding strategy of Gates (196?) is adumbrated. We have then subjected this implied theory of tendering to analysis insofar as it is possible to evaluate economic theories such as these which provide little opportunity for empirical testing. The outcome of this evaluation has been that tendering theory, as implied by Gates, does not perform well in terms of accuracy of forecasts and informative content, and that there are inconsistencies in the logic, especially with regards to the assumed profit maximisation behaviour. As a result we have been forced to conclude that bidding strategy, as a prescribed **practice** is ill-founded and this may be one reason why there is little evidence of its adoption in practice or significant development in method. As has been shown, bidding strategy falls uneasily between game theory, decision theory and the theory of auctions. This, together with the lack of theoretical development in the way of contrasts with conventional economic theory is, in itself, cause for concern, and we have offered several reasons for the existence of this situation including the long running 'controversy' over the method of calculating probabilities. Whilst not proposing an abandonment of the field, we do urge caution in the development of yet further refinements of methods for bidding strategy in the absence of a suitable theoretical framework. In particular, the need to incorporate information concerning market conditions in future bidding models is highlighted.

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