Raftery curve construction for tender price forecasts

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RAFTERY CURVE CONSTRUCTION FOR TENDER PRICE FORECASTS

(FORMERLY 'THE RAFTERY CURVE')

ABSTRACT

Raftery (1993) has suggested that project cost estimates be presented in the form of cumulative probability functions (termed here 'Raftery Curves') rather than the current practice of single point estimates. This paper describes a method for the empirical construction of the Raftery Curves for tender price forecasts. This is applied to ten previously published data sets gathered throughout the world. In comparing the resulting curves, the most consistent feature is shown to be the shift associated with to the number of bidders entering bids for contracts. This is examined both in terms of bias and consistency. Contrary to some previous studies, no evidence was found of any trends related to the value size of projects.

Keywords: Cost, time, forecasting, probability, bidders, range estimates.

INTRODUCTION

"The construction industry has a reputation for delivering expensive projects late. Forecasts of project costs are frequently exceeded because of the lack of repetition caused by the bespoke nature of the industry's products, its transient itinerant production teams, and volatile market" (Raftery, 1993:7). Training people to increase their understanding and awareness of risk attitude and to help them make consistent decisions using informal approaches may be the best solution. What is needed, therefore, are financial forecasts which explicate the uncertainties in a simple form for practice and to present the practitioner decision-maker with an unbiased, consistent and unequivocal statement of the true nature of the forecast. According to Raftery, many of the difficulties encountered in practice, particularly in communicating estimates of individual project costs, would be overcome by presenting these estimates in probabilistic form.

The curve shown in the lower diagram of Fig 1 illustrates his position. Here the estimated project cost, in millions of pounds, is predicted to lie within a range, shown qualitatively as ranging from 'low' to 'high'. On the vertical axis is shown the percentage of chance that the actual project cost will be below any given cost. The vertical line in the middle of the diagram indicates the best estimate for the project so that any values to the right of this can be taken to be 'conservative', that is there is less than a 50/50 chance that the actual project cost will exceed this figure. Conversely, any values to the left of this figure are regarded as 'risky' as there is less than a 50/50 chance that the actual project cost will be lower.

To date, little has been written concerning the calibration of Raftery curves. One obvious

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approach is for the calibrator to do this subjectively by relying on experience and professional judgement. To be more objective requires the acquisition and analysis of data concerning past estimated, and their associated accounted (actual), costs. There are problems, however, surrounding the use of accounted costs in the construction industry:

- they are not usually readily available.
- when they are available, their accuracy is not vouchsafed
- due to the long delay between the estimated and the related accounted costs, significant changes in circumstances (eg., design changes, economic conditions) are likely to have occurred.

An alternative to the use of accounted costs is to construct Raftery Curves for tender price forecasts. Here the purpose is to predict the likelihood of the lowest tender price being above or below some percentage of the forecast. This overcomes all the problems involved with accounted costs as they are available readily and timely.

There are two distinct approaches to constructing Raftery Curves for tender price forecasting. The first is to synthesise the individual variability of each of the components of the project via, for instance, a bill of quantities or schedule of rates. The second, and the one used in this paper is to use empirical analysis of past projects. It is shown that applying this method to several datasets gathered from around the world enables comparisons to be made and some generalisations drawn - particularly concerning the effects of the number of bidders.

REALISATION

There is no real difficulty in constructing a tender price forecast Raftery Curve from existing contract records. Fig 2 shows how this can be done using data provided by a USA building contractor (Broemser, 1968). Here the data set contained records of the contractor's cost estimates over a series of 76 building contracts in the 1960s.

The cost estimate for each contract is compared with the lowest bid, for each contract to give a measure of percentage 'accuracy' of the estimate. These percentages are then grouped into 5 percent bands and the number falling within each band is recorded. The dark shaded histogram shows the results of this for Broemser's data to which a normal distribution curve has been fitted. The superimposed Raftery Curve shows the cumulative version of this distribution curve. It can be seen from this graph that the lowest bid ranges from around 20% below to 20% above the estimate and, by reading off the vertical axis, the percentage of contracts can be found for which the lowest bids are below some percentage of the estimate. Dividing the percentage on the vertical axis by 100 allows this to be treated as a probability.

So, when Broemser's contractor calculates the cost estimate for the next contract, the Raftery Curve can be used to find the probability that the lowest bid will be within a range of plus or minus 1%, 5% or whatever percentage wanted. Conversely, the contractor can

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also find the range within which the lowest bid is likely to fall. In this case, there is a 95% chance that the lowest bid will fall within plus or minus 11% of the estimate.

Further Raftery Curves have been developed in this way for a series of datasets[1], including designers' tender price forecasts, as Raftery curves can also be constructed for designers as a means of informing on the likely range of the lowest bid for a contract. These data sets, including Broemser's set, are summarised in Table 1, and the resulting distribution curves are shown in Fig 3.

From a practical point of view, some improvement is needed on this method. Firstly, the purpose of the Raftery Curve is to provide information for a specific contract and yet to construct accurate curves by this method, data for many contracts have to be aggregated. Of course, the data could be restricted to a sample containing, say, similar buildings. This would give a more representative curve but, with less data, would be less accurate. Secondly, most firms in the construction industry are very small and therefore are not able individually to assemble data on a big enough scale to match the examples provided here.

Ideally, a specific contract curve needs to be constructed by reference to the characteristics of that contract. In other words, a **model** is needed which embodies the relationship between the relevant contract characteristics and Raftery Curves so that, by entering the values of a new contract into the model, an accurate prediction of the curve for that contract can be made.

How can the relationships needed for such a model be found? The first problem encountered in this is the severe lack of data on the subject. Most estimators do not record the kind of information needed and the major procurement agencies who keep suitable records on any scale do not usually allow access to such records. On the other hand, there have been several studies in related topics. Each of these sheds a little light on the problem.

The relationships sought can be divided into either local or universal relationships. The main interest here is in the universal relationships. By examining several sets of data, it is hoped to detect common trends. All the 10 distribution curves shown in Fig 3 for example have been constructed on the Normal model, which means they differ only in respect of their spread and position on the horizontal axis. In terms of estimating performance, these can be interpreted as measures of consistency and bias respectively.

In Fig 3, the narrow lines represent the smaller datasets (less than 100 contracts) and the wider lines represent the larger datasets (over 100 contracts). There are clear differences between the data sets, both in terms of consistency and bias. The contractors' data (first four datasets) are much more consistent whilst the designer/consultant data sets vary greatly both in bias and consistency. Why should this be?

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[1] Details of the nature, origin and timing of the estimates used can be found in the original papers containing the datasets.

There are several possible reasons: the contractors are expected to be better than the consultants as they have access to better information on actual construction costs and spend far more time in preparing their estimates. Also 'McRoad' and 'USA Govt', with the greatest inconsistency, are concerned with engineering projects which are known to be more difficult to estimate.

For a more comprehensive account, we need to consider the general field of construction price forecasting, and the little theory that exists on the subject. To date, the main emphasis on research in this area has been in target related matters - contract size, type, geographical location, procurement system and number of bidders - as well as more environmental aspects such as the general economic climate, but with mixed results. Of these, the most recurring 'effect' is, perhaps surprisingly, the number of bidders.

NUMBER OF BIDDERS EFFECT

Bias

The data were ordered against the number of bidders in each contract auction and the mean trends modelled by a bivariate regression analysis with the a power term selected from -2, -1.5, -1, -0.5, 0.5, 1, 1.5, 2.0 or log according to the r^2 obtained. The results are summarised in Table 2. This shows each database with number of contracts, best r^2 obtained, power/log term, regression constant and coefficient and significance of the Kolmogorov-Smirnov test for normality on the residuals (the 'upper sd' and 'lower sd' figures are described later).

The regression curves are illustrated in Fig 4 with the line thicknesses again being shown in proportion to the size of the dataset involved. This confirms the general downward trend of the means in nine of the 10 data sets and a concave asymptotic shape for seven out of these nine. It can also be seen that all four of the contractor's data sets converge asymptotically close to zero error for contracts with four or more bidders. For the non-contractor data, the pattern of the trend lines is less similar but there would appear to be a drop in price levels of from around plus 10% to minus 10% over a range of 2 to 15 bidders.

Several studies have been published which report on this 'effect'. Runeson and Bennett's analysis of 240 New Zealand Ministry of Works and Development building contracts revealed a similar trend averaged over each bid set (Runeson and Bennett, 1983). The phenomenon also occurred with Handscomb's analysis of 1100 USA Corps of Engineers DD813 averaged entries (Hanscomb Associates, 1984).

The United Hospital Fund of New York publish a similar model for estimators to enable adjustments to be made where there are more or less than 6 bidders involved (Hanscomb Associates, 1984). This has been checked and revised by Hanscomb, based around seven bidders (Hanscomb Associates, 1984).

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Other studies have found additional effects. Harvey's (1979) analysis of 2401 public works contracts across all Canada found the trend differed according to the value size of contracts although this was reversed in Flanagan and Norman's (1983) analysis of 63 UK County Council contracts. Value size effects similar to Harvey's were also found in Wilson *et al's*, (1987) analysis of 410 Australian State of Victoria Public Works contracts together with a smaller effect due to the presence or absence of a client provided bill of quantities in the procurement process. Harvey also found differences between various types of contracts.

Finally, in one of the most interesting studies of this kind, De Neufville's analysis (Neufville de *et al*, 1977) of 167 Massachusetts Bureau of Building contracts showed a clear distinction between 'good years', when there was much work on the market, and 'bad years', when bidders were desperate for work.

On this evidence, it seems there may well be a universal 'number of bidders effect'. What is less obvious however is the status of the other 'effects' observed in these studies. Apart from value size, none of these other effects have yet been tested by replication. Even with value size, the effects are not at all consistent. A major study by Morrison and Stevens (1980) over several estimating organisations found the effect to change from one organisation to another.

To check this with our data sets, each set was split into larger and smaller contracts after adjusting for inflation where possible, and a trend line was fitted to each (Tables 3 and 4). The differences between the trend line for larger and smaller contracts are shown in Fig 5. All of the eight analysable data sets show a minimum difference between errors at around eight bidders, the typical norm for construction contract auctions, with larger contracts being underestimated between zero and 6-7% more than smaller contracts.

For auctions with over eight bidders, six of the 8 data sets continue to show larger contracts more underestimated with all except one of these being within 4% difference. Below eight bidders, there is a suggestion that the reverse might apply for most of the data sets. Overall, it is difficult to see any non-local effect other than a tendency to underestimate larger contracts a few percentages more than smaller contracts.

Consistency

A power/log bivariate regression was carried out on number of bidders variable with the absolute values of the residuals arising from the 'bias' analysis. Where the main regression in the bias analysis had failed the Kolmogorov-Smirnov test, the positive and negative residuals were analysed separately. The results are shown in the 'upper sd' and 'lower sd' sections of Table 2. These indicate the trend of the consistency of the forecasts in terms of standard deviation (Gujarati, 1988:330) and are illustrated in Fig 6. This shows that seven data sets decrease whilst three increase with number of bidders. The contractors' standard deviations are the smallest over the 2 to 7 bidder range and, apart from the USA Govt data, all are within 11% or less for 7 bidders or more, and diminishing to 7% or less at 14

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bidders for all but 2 of the data sets.

There are no published studies on the effects of other variables on consistency in relation to the number of bidders. Tables 3 and 4 summarise the results of the analysis and Fig 7 illustrates the differences in forecast standard deviations between larger and smaller contracts. For four of the data sets, the forecast standard deviations are greater for larger contracts and four are less indicating no obvious universal trend for contract value size.

CONCLUSION

This paper shows how Raftery Curves for tender price forecasts may be constructed both empirically and theoretically as well as having the additional benefit of helping remove some of the difficulties encountered in practice. This involves ordering the percentage differences between tender price forecasts (estimates) and the actual lowest tenders and converting the resulting frequency distribution into parametric form. Comparisons made when applied to previously published data gathered from around the world, suggest that systematic shifts (biases) in the curves are related to the number of bidders involved in setting the contract value and systematic changes in shape (consistency) are related to the type of project (building/engineering) and purpose of estimate (contractor's cost estimate/engineer's price estimate). Once allowing for number of bidders, however, no evidence was found to suggest the existence of any systematic effects related to contract values. This is contrary to previous published work in the field (Morrison, 1984).

One surprising result is the lack of any clear relationship between consistency and the number of bidders. This brings into question the efficacy of bidding models, which predict a decrease in consistency with increasing number of bidders.

It should be noted that only a few obvious predictor variables have been used in the analysis. Many others are possible, such as the type and geographical location of the project, procurement system and prevailing general economic climate. In addition, the work reported here relates only to aggregated contract data obtained from individual companies and therefore precludes any analysis of the **individual estimators** involved. Other work by Skitmore *et al* (1990) investigating the accuracy of early stage contract price forecasts found significant differences in both bias and consistency between individual estimators that were attributable to the estimators' specific project estimating experience. It is suggested therefore that any further work in predicting Raftery Curves make due allowance for this phenomenon.

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Table 1. Summary of datasets used in the analysis

Name	Description
Broemser	a contractor's cost estimates for 76 USA building contracts in the 1960s (Broemser, 1968).
London	a contractor's cost estimates for 36 London building contractors in 1979 (Skitmore, 1986).
Benjamin	a contractor's cost estimates for 130 USA building contractors in the 1960s (Benjamin, 1969).
Shaffer	a contractor's cost estimates for 50 USA building contractors in the 1960s (Shaffer and Micheau, 1971).
Runeson	State of Victoria quantity surveyor's price estimates for 154 building contracts, mainly housing, in the 1970s (Runeson, 1976).
McBuild	Belgian public works engineer's price estimates for 129 building contracts, mainly housing, in the 1970s (McCaffer, 1976).
Gunner	a Singaporean private quantity surveyor's price estimates for all 181 of the practice's projects over a ten year period in the 1980s and including many of the major construction projects carried out in Singapore during that time.
Tan	a UK Local Authority Architect's Department quantity surveyor's price estimates for 33 small building projects in the 1980s (Tan, 1988).
McRoad	Belgian public works engineer's price estimates for 154 roads contracts in the 1970s (McCaffer, 1976).
USAGovt	a major USA Government aeronautical agency cost engineer's price estimates for 291 contracts in the 1970s. The data are restricted to construction work although much of this is of an engineering nature.

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Table 2: Percentage low bid above estimate vs number of bidders

Source	N Cases	Regression					Upper sd				Lower sd			
		r^2	Trans	Const	Coeff	K-S	r^2	Trans	Const	Coeff	r^2	Trans	Const	Coeff
Broemser	76	.0092	-2.0	-1.293	+15.3761	ns	.0180	-2.0	+4.787	-13.1903	.0180	-2.0	+4.787	-13.1903
London	34	.0187	-2.0	+0.422	-46.3808	ns	.0371	+1.0	+6.769	-0.4927	.0371	+1.0	-6.769	+0.4927
Benjamin	130	.0272	-2.0	-0.713	+23.7288	ns	.1482	-1.0	+0.940	+21.5442	.1482	-1.0	-0.940	-21.5442
Shaffer	50	.0345	-2.0	-3.233	+22.9961	sig	.2316	-1.5	+6.268	-12.2027	.0505	-0.5	-18.431	+19.4773
Runeson	154	.1162	log	+10.046	-7.4152	sig	.0275	+1.0	-16.757	+0.5467	.0607	log	+17.505	-4.3108
McBuild	129	.2784	+2.0	+16.171	-0.1991	ns	.0209	-1.5	+11.237	-23.6995	.0209	-1.5	-11.237	+23.6995
Gunner	179	.0396	-1.0	-8.616	+15.3928	sig	.0060	-2.0	-6.442	-24.5822	.0648	-1.0	+2.562	+24.5479
Tan	33	.0706	+1.5	+20.479	-1.2569	ns	.0222	+2.0	+17.506	-0.1355	.0222	+2.0	-17.506	+0.1355
McRoad	154	.1456	-1.5	+90.001	+90.4888	sig	.0589	+0.5	+31.944	-8.2786	.0206	-2.0	-11.077	-25.3297
USA Govt	292	.0707	-0.5	-35.311	+62.8240	ns	.0277	-2.0	+16.128	+49.3256	.0277	-2.0	-16.128	-49.3256

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Table 3: Percentage low bid above estimate vs number of bidders'large' contracts

Source	N Cases	Regression					Upper sd				Lower sd			
		r^2	Trans	Const	Coeff	K-S	r^2	Trans	Const	Coeff	r^2	Trans	Const	Coeff
Broemser	38	.0048	1.0	-1.944	+0.1458	ns	.0536	log	+7.666	-1.9396	.0536	log	-7.666	+1.9396
Benjamin	65	.0371	1.0	+2.405	-0.3472	ns	.0143	log	+4.504	-0.8150	.0143	log	-4.504	+0.8150
Shaffer	25	.0419	-2.0	-3.418	+25.6812	ns	.0807	-1.5	+7.663	-19.0493	.0807	-1.5	-7.663	+19.0493
Runeson	77	.1508	log	+10.496	-7.3511	ns	.0385	-2.0	+3.942	+35.6858	.0385	-2.0	-3.942	-35.6858
McBuild	64	.1534	+1.0	+24.087	-2.3534	ns	.0443	-1.5	+12.826	-33.3917	.0443	-1.5	-12.826	+33.3917
Gunner	63	.0725	log	+5.037	-4.7688	ns	.0167	+1.0	+10.145	-0.2366	.0167	+1.0	-10.145	+0.2366
McRoad	77	.2157	-1.0	+83.322	+94.0254	ns	.0415	log	+23.739	-6.3320	.0415	log	-23.739	+6.3320
USA Govt	146	.0810	+1.0	+1.686	-1.6457	ns	.0236	-1.5	+12.658	+25.2439	.0236	-1.5	-12.658	-25.2439

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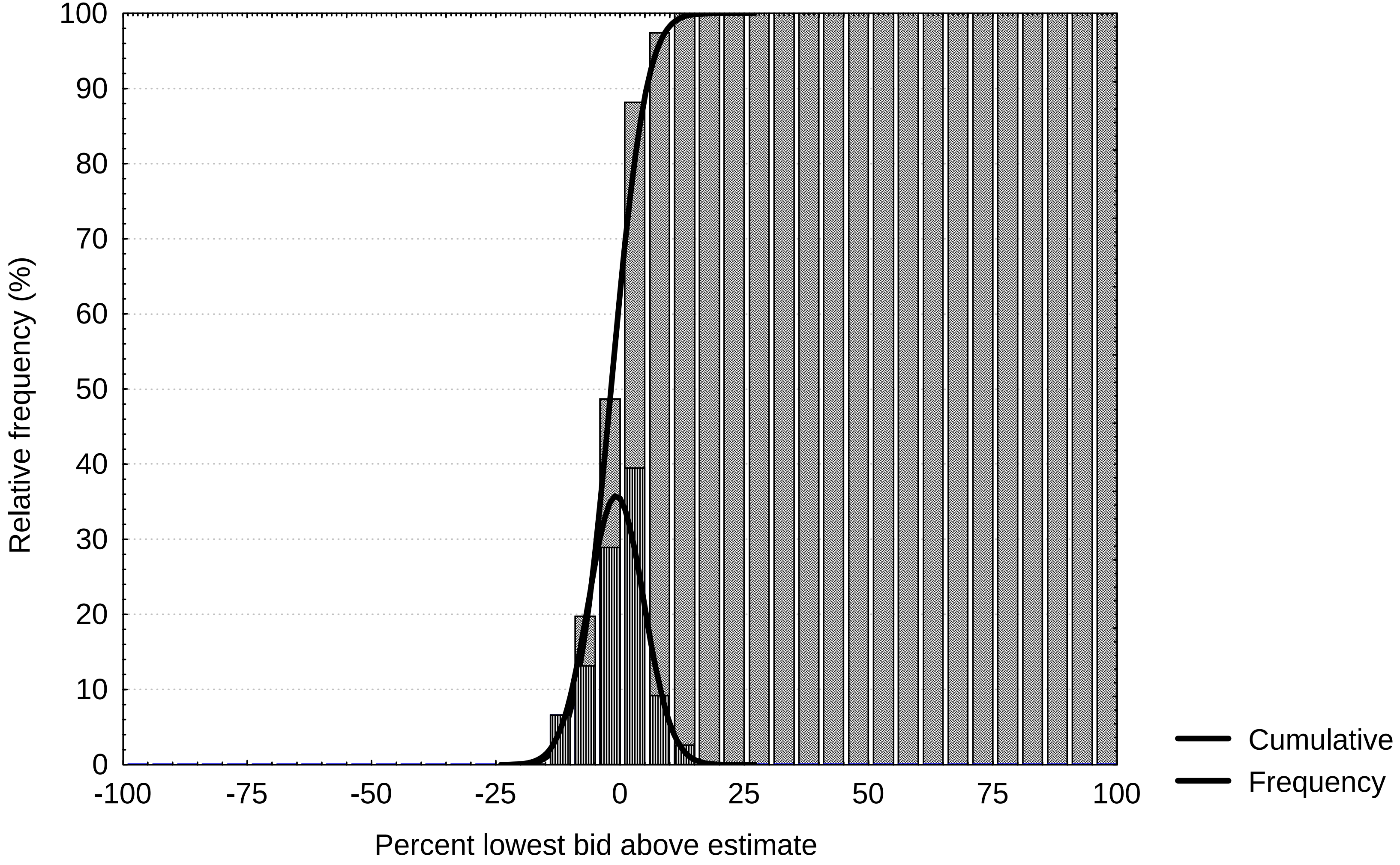
Table 4: Percentage low bid above estimate vs number of bidders 'small' contracts

Source	N Cases	Regression					Upper sd				Lower sd			
		r^2	Trans	Const	Coeff	K-S	r^2	Trans	Const	Coeff	r^2	Trans	Const	Coeff
Broemser	38	.0468	1.0	+2.923	-0.4969	ns	.1048	log	-1.348	+3.0419	.1048	log	+1.348	-3.0419
Benjamin	65	.0399	-2.0	-1.060	+31.5203	ns	.1862	-0.5	-4.782	+26.1660	.1862	-0.5	+4.782	-26.1660
Shaffer	24	.0287	-1.0	-7.999	+14.0035	ns	.0665	-1.5	+8.686	-14.6122	.0665	-1.5	-8.686	+14.6122
Runeson	76	.1039	log	+8.092	-7.0223	sig	.0644	-2.0	+4.032	+32.7458	.0849	-2.0	-3.855	-58.9451
McBuild	65	.3387	+1.0	+24.407	-3.1310	ns	.0122	-2.0	+9.870	-27.6887	.0122	-2.0	-9.870	+27.6887
Gunner	61	.0307	-1.0	-13.372	+22.9648	ns	.0666	+1.0	+25.216	-1.5085	.0666	+1.0	-25.216	+1.5085
McRoad	76	.1303	-1.0	+80.700	+67.3943	ns	.0361	+1.0	+18.989	-1.4707	.0361	+1.0	-18.989	+1.4707
USA Govt	145	.0562	-1.5	-17.483	+75.0556	ns	.0076	+1.0	+22.521	-0.3969	.0076	+1.0	-22.521	+0.3969

Fig. 1. The Raftery Curve (reproduced from Raftery (1993)

Fig 2: Raftery Curve constructed from Broemser's (1968) data



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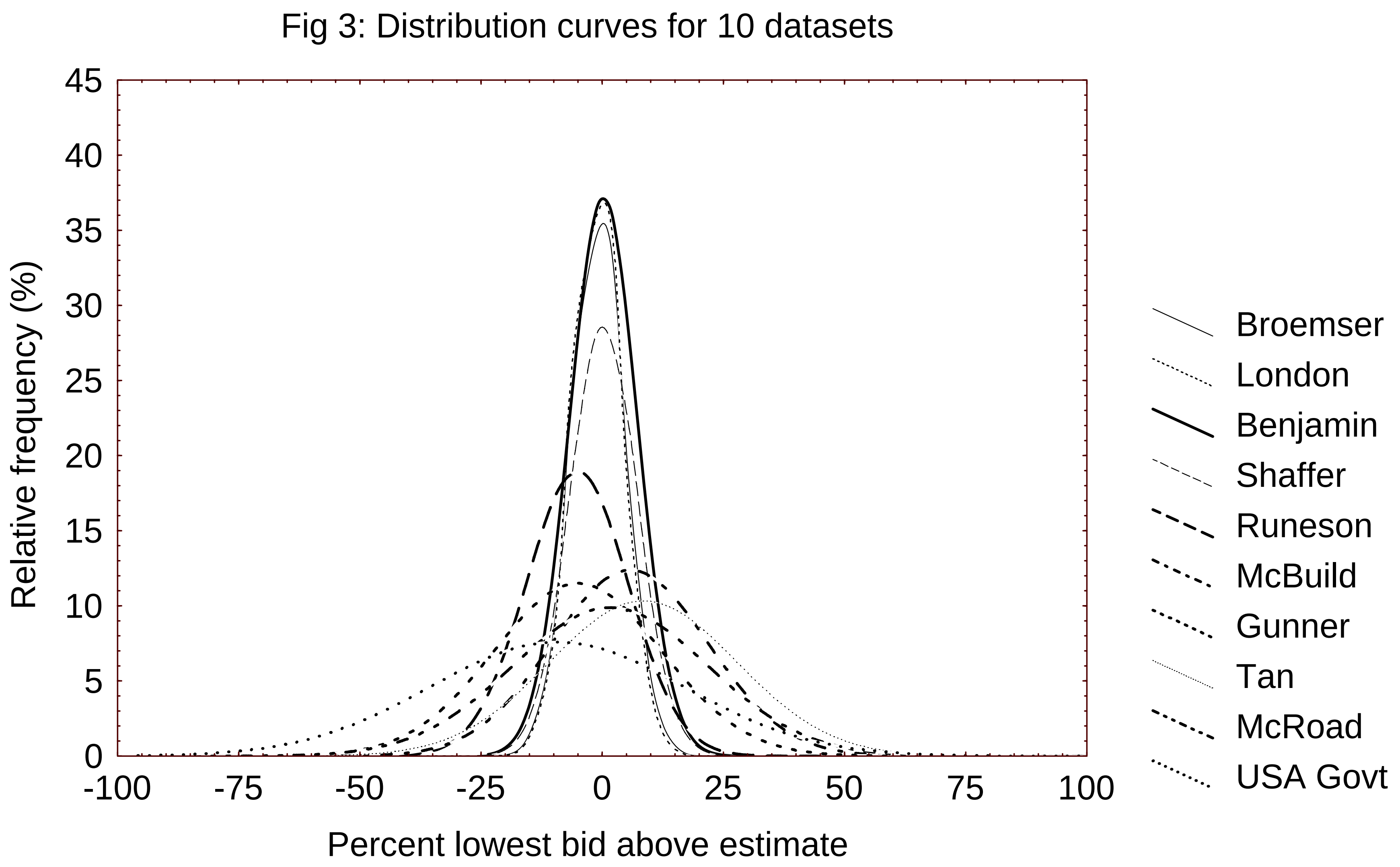

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Fig 4: Mean trend for all datasets

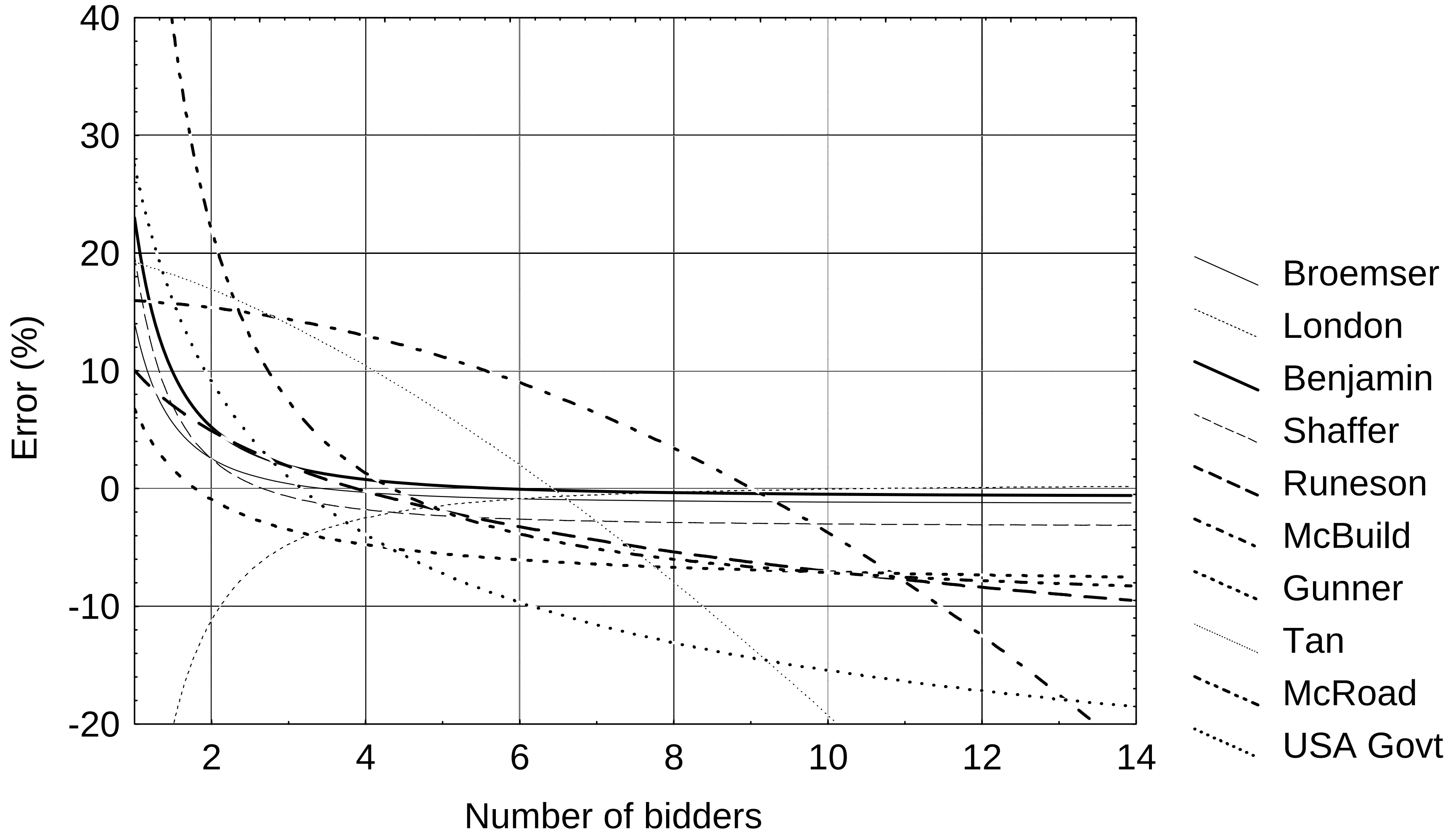

Fig 5: Difference between mean trends for large and small contracts

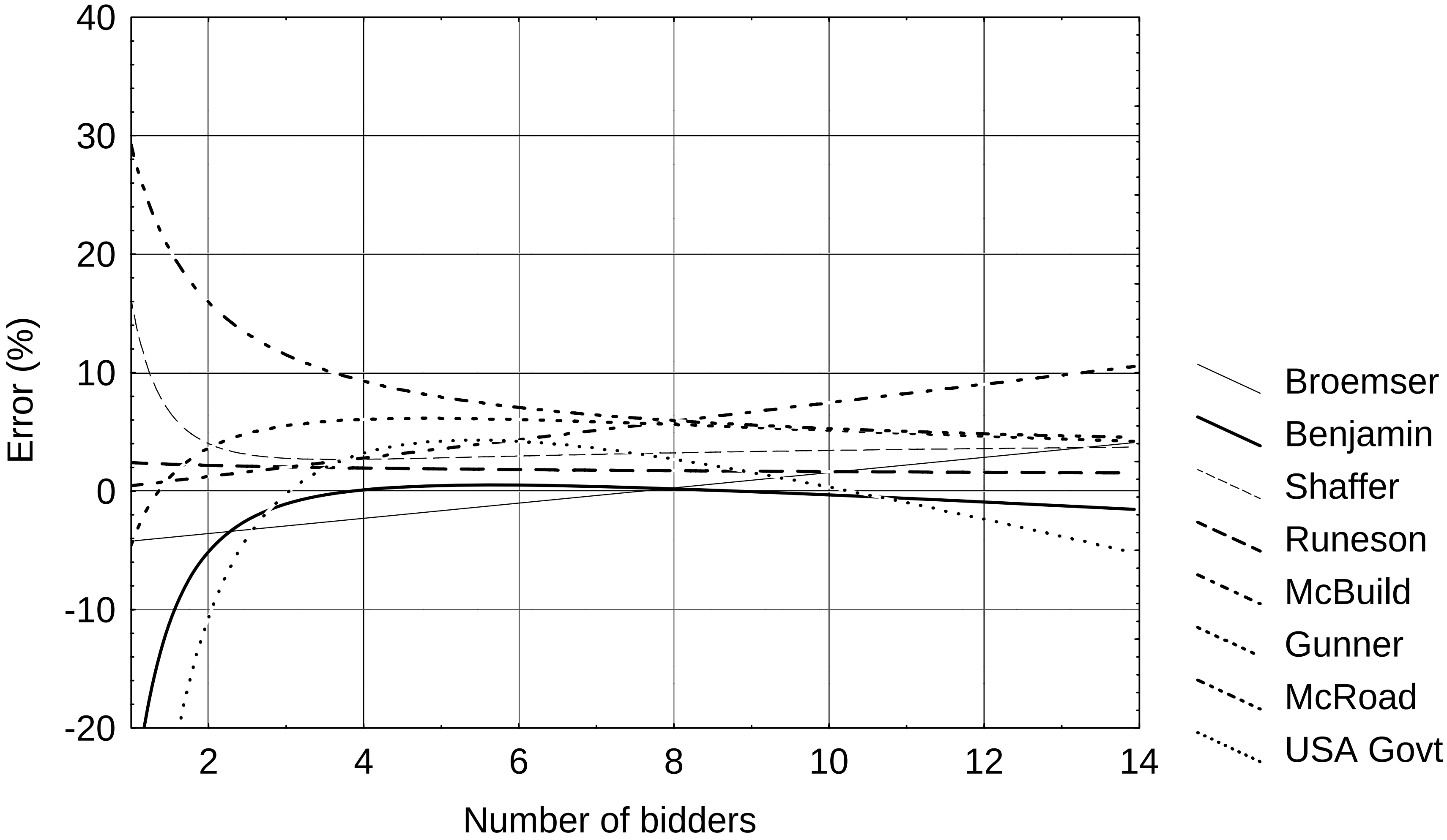

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Fig 6: Standard deviation trend for all datasets

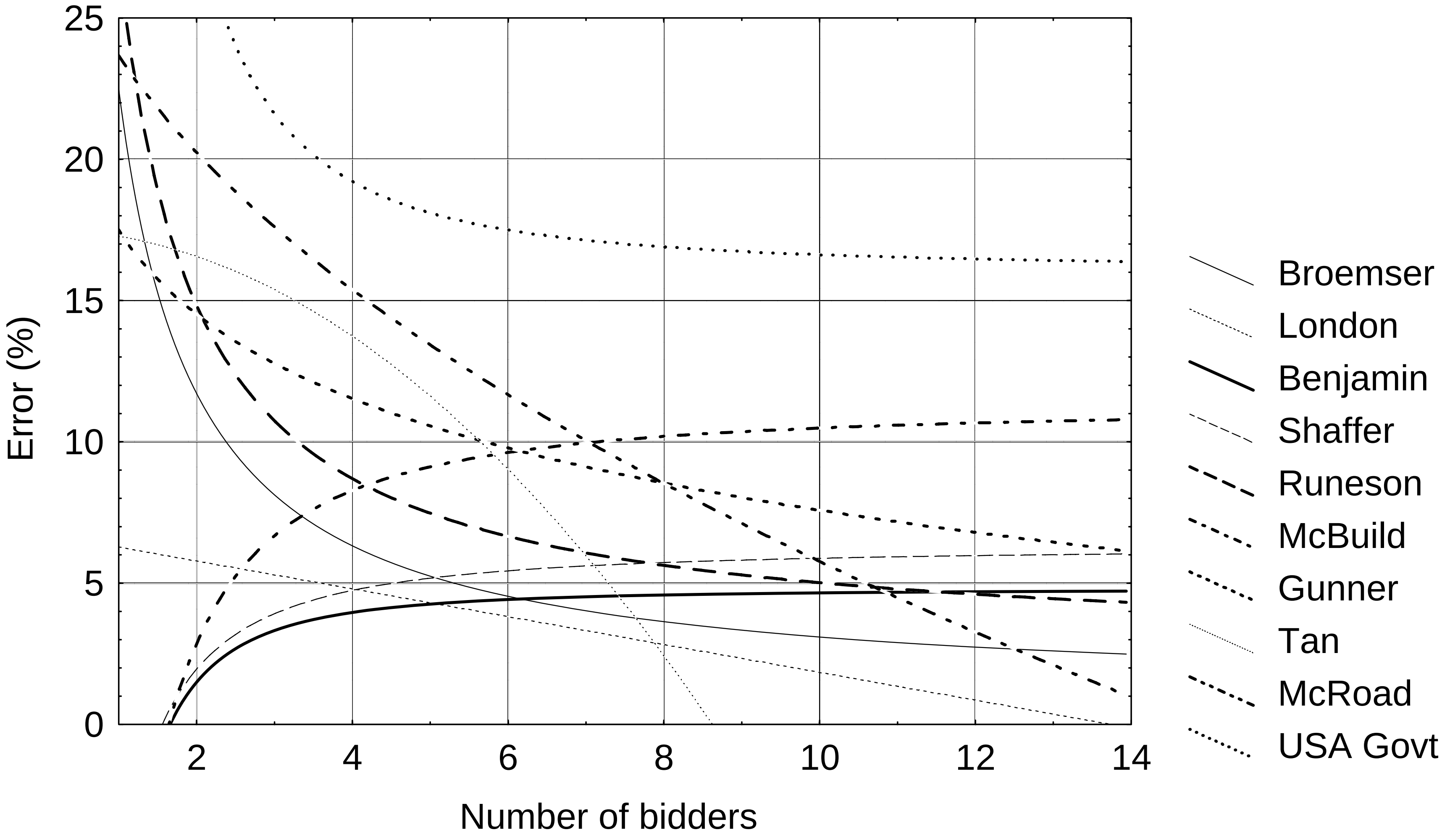

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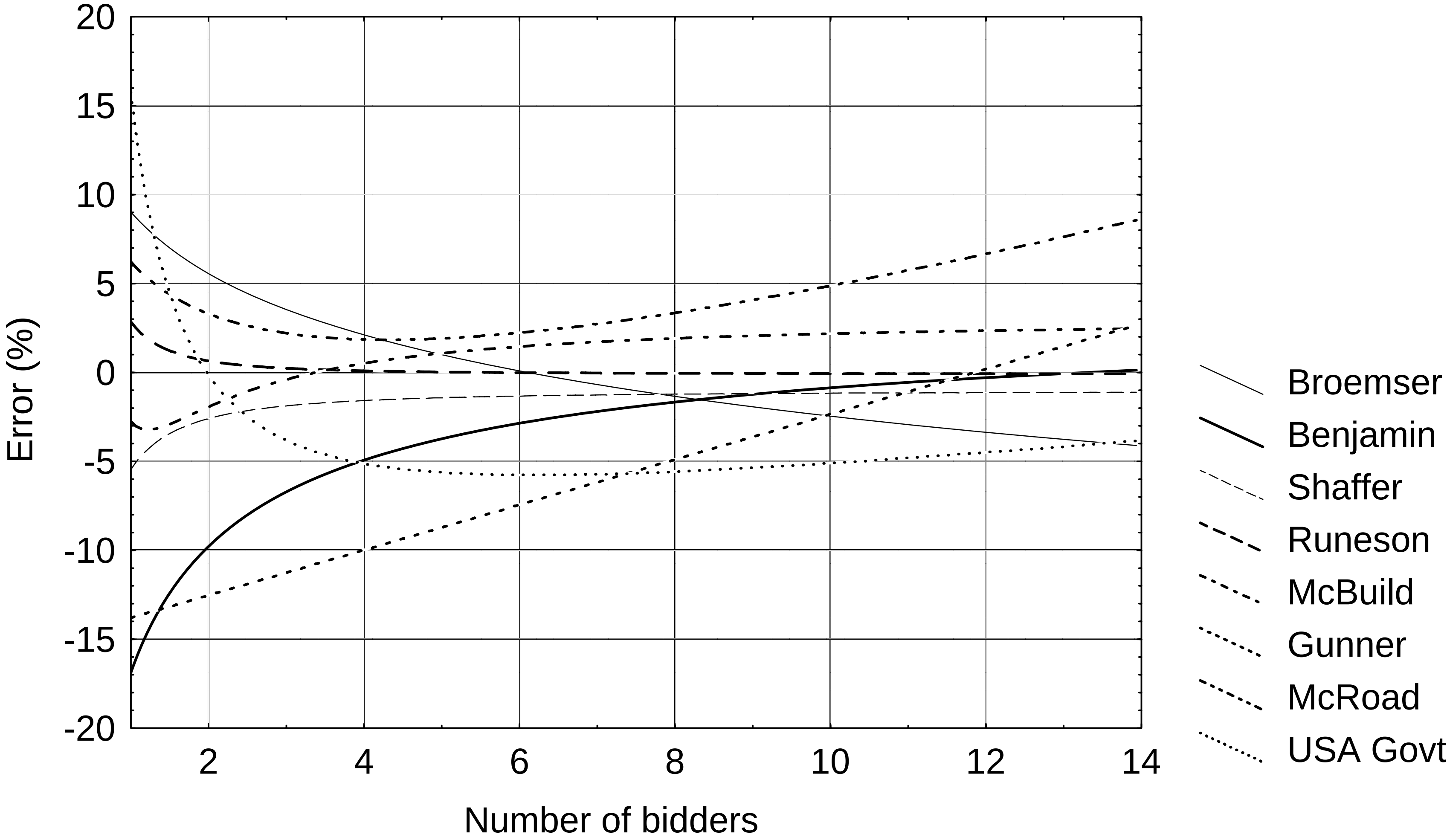
Fig 7: Difference between standard deviation trends for large and small contract



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