Scoring Rules and Price-Quality Correlation in Public Procurement Auction Data

by

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Abstract

The paper investigates the observed correlation between price and quality in multidimensional public procurement auctions, using data from the Swedish public sector. The scoring rules applied in these auctions are both independent and interdependent scoring rules. The paper illustrates the buyer's incentive to distort his true assessment of the quality dimension in bids subjected to an interdependent scoring rule. Estimating the Spearman's rank order correlation, we find that the correlation between price and quality equals zero when an interdependent scoring rule is applied, whereas the same coefficient under the independent scoring rule takes the value of 0.31, a result in line with similar estimates obtained in price-quality tests of private consumer goods.

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1. Introduction

The auctioning of public procurement contracts in many cases takes the form of a multidimensional auction. The decision on the allocation of the contracts is based not only on offered prices but also on quality or performance dimensions. Beside the price, firms offer a level of quality they promise to ensure. Each bid, in terms of a price-quality pair, is then assigned a score according to a scoring rule, which is known by the bidders prior to bidding. From the buyer's perspective, the scoring auction outperforms the price-only auction. Under some conditions, an optimal scoring auction should underweight the buyer's actual valuation of quality, but given low commitment power of the buyer to stick to the scoring rule when evaluating the bids, the only feasible scoring rule is the one that corresponds to the buyer's preferences. Generally, in a setting where the suppliers' private information is one-dimensional in the price-quality space, the optimal scoring auction has a scoring rule that is linear in price (Che (1993), Asker and Cantillon (2008)). Now, studies of observed scoring rules applied in public procurement auctions suggest that the design of scoring rules varies a lot. Stilger *et al.* (2015) simulate and compare the outcome from about 40 different scoring rules - collected from academic and practitioner publications. The formulation of the scoring rules differ, not only in their algebraic expressions, but also in terms of the information that is required to compute the score of an individual bid. Broadly, the scoring rules observed in the field can be categorized in two types. The first type of scoring rules can be labelled as independent rules, where the scoring of a bid is based on how the attributes of the individual bid are related to some fixed reference values, which are announced to bidders prior to bidding. Very often, these rules involves a transformation of the bid's quality level or quality score into a monetary valuation, which is discounted from the offered price. The bidder who submits the lowest quality-discounted price, will be the designated winner. The magnitude of the monetary values for different levels of quality then reveals the buyer's preferences over price and quality. The second type of scoring rules are interdependent scoring rules, where the scoring of a bid, besides the bid's own attributes, also depends on attributes from other bids submitted in the auction (lowest price, highest price, average or median price, highest scored quality etc).[1] The use of the later scoring rules in public procurement seems to be relatively widespread within the EU, but they are also to be found in countries and organizations outside the EU (see Stilger *et al.* (2015), Fuentes-Bargues and Gonzalez-Gaya (2013), Bergman and Lundberg (2013), Mateus

[1] The same types of scoring rules are sometimes also called absolute and relative scoring rules (Stilger et al (2015). See also Bergman & Lundberg (2013) for a categorization of scoring rules.

et al. (2010), Pauw and Wolwaardt (2009)). The inclination to apply an interdependent scoring rule is possibly to be explained by the wording in the legislative framework regulating public procurement in the EU. The law states that contracting authority "shall specify, in the procurement documents, the relative weighting which it gives to each of the criteria chosen to determine the most economically advantageous tender, except where this is identified on the basis of price alone".[2] Our conjecture is that the wish to literally comply with the EU directives, has induced many procuring agencies to strive towards a method that scores prices instead of assigning monetary values to quality. The general method applied is to score the bid price and the level of quality separately, and then multiply each score with a relative weight. The bid with the highest weighted total score is the winning bid. Alike the transformation of quality into a monetary value, the transformation of a price into a score requires a reference value. Now, many national procuring agencies seem to choose an endogenous price, generated in the bidding process, as a reference point, instead of choosing a fixed value which is announced prior to bidding. This would remove the scoring interdependency across the bids.[3] The tenders we have in our data set, in which an independent scoring rule has been applied, all use the method where prices are discounted with the buyer's monetary valuation of quality. There are no tenders using a weighted score method with an exogenous reference price.

The inherent problem with an interdependent scoring rule is the difficulty for a supplier to infer from the scoring rule which of his possible combinations of price and nonmonetary attributes would generate the highest score in the auction. The supplier must make conjectures, not only about the behaviour of his expected worst competitors, but also about the behaviour of expected inferior suppliers that may participate in the auction. The competitive strength of the supplier's submitted price will be determined by factors which are not due to his worst competitors. Hence, the suppliers' choices of offered quality levels may not be adequately captured in their offered prices, leading to a blurry relation between price and quality. Also, from the buyer's perspective, the interdependent scoring rule may generate an (*ex ante*) unappealing winning bid with a price far too high, incurring a lower utility than that of a losing bids. For that reason a buyer, lacking full commitment power, may adjust the score of the nonmonetary attributes of

[2] Directive 2014/24/EU, Article 67

[3] Although the use of an exogenous reference value removes the scoring interdependency across bids, it is not a panacea when scoring prices. The buyer's choice of the location of the reference value may be decisive upon the relative ranking of the prices.

one or of several bids in order to rank the bid, which maximizes the buyer's utility, as the winning bid.[4]

In this empirical paper, centred on scoring methods in multi-dimensional Swedish public procurement auctions and the trade-off between price and quality, we consider three related issues. First, by estimating the Spearman's rank order coefficient (Spearman's rho), we investigate to what extent a higher bid price in a tender also implies a higher assessed quality level. Second, we illustrate the buyer's incentive to distort his true assessment of the quality dimension in bids subjected to an interdependent scoring rule, and then test the hypothesis that observed differences in price-quality correlation can be explained by scoring method applied. Third, we examine the relation between the size of the weighted parameter attached to price in the scoring rule and the selection of the bid with the lowest bid price as the winning bid. The data we use is collected from Swedish public procurements carried out during the period 2006-2016, in total 1 927 bids submitted in 441 tenders.

The main finding of our empirical analysis is that the overall correlation between price and quality is close to zero, but differs substantially when controlling for the type of scoring rule applied. Under the independent scoring rule, we find that the estimated median value of Spearman's rank order correlation is 0.31, a result in line with similar estimates obtained in price-quality tests of private consumer goods.

The rest of the paper is organized as follows. In Section 2 we survey related theoretical and empirical literature. In Section 3 we provide an illustration of the buyer's incentives to distort his preferences for quality when bids are evaluated in interdependent scoring rule. Section 4 presents the data and the outcome from the econometric analysis. Section 5 summarizes the paper.

2. Related literature

The literature on multidimensional procurement auctions is quite rich. One branch of the literature is devoted the study of the optimal design of scoring auctions (see Asker and Cantillon (2010) or Nishimura (2015)) for shorter surveys). The general wisdom is that, from the buyer's perspective, a price-quality score auction is preferred to a price-only auction with minimum

[4] In general, a buying entity has to make its scoring of prices and of nonmonetary attributes of each bid public when announcing the ranking of the bids, but – in contrast to the scoring of the prices - the buyer's assessment and scoring of quality is open for arbitrariness.

quality threshold. In a one-dimensional quality framework Che (1993) derives the optimal buying mechanism, in which price enters the scoring rule linearly. Given that the buyer can fully commit to the scoring rule, the scoring rule penalizes quality relative to the true preferences of the buyer. The model in Che (1993) is extended by Branco (1997) who allows for correlation among firm's cost. His analysis shows that a two-stage mechanism – bidding and bargaining - is needed in order to obtain an optimal outcome. Asker and Cantillon (2008) also take the model by Che (1993) a step further, allowing for suppliers to have multidimensional private information. They show that the scoring auction, with a linear-in-price scoring rule, still dominates the price-only auction and also dominates a menu-auction as well as a beauty contest. In a multidimensional environment, David *et al*. (2006) develop scoring functions for different auction protocols where the multi attributes of an auctioned contract are utility independent, i.e., the buyer has an additive utility function. A weight is attached to each of the quality values. The scoring rule corresponds to same form as the utility function, but with downward distorted quality weights. The size of the weight distortion, relative the buyer's real utility, is negatively related to the number of expected bidders. Nishimura (2015) examines conditions on the suppliers' production costs under which the optimal scoring rule can take the form of an additively separable function with weighted criteria. The analyze shows that a sufficient condition to implement an optimal scoring rule, by means of an additively separable function, is that quality attributes are cost complements, that is, the suppliers face economies of scope when increasing the level of quality attributes.

Despite the frequent use of various scoring rules in public procurement, the number of empirical studies, analyzing the effects of changes in the scoring rule, are relatively few. Albano *et al*. (2008) investigate the impact of independent and interdependent scoring rules on bidding behavior in the procurement of IT services, auctions conducted by the Italian Ministry of Economy and Finance. Overall, the bids exhibit a negative correlation between price and quality, which, according to the authors, may be due to the potential difficulty for a procuring entity to adequately reflect its preferences for the price/quality trade-off in the tender designs. Their empirical analysis indicates that the use of an independent scoring rule induces bidders to bid more aggressively than they do under the interdependent scoring rule. The argument is that under the former rule, bidders can easier identify the price/quality trade-off, which facilitates bidding and encourages to more aggressive bidding on price. Their paper also develops a price/quality index which shows the (relative) change in price due to a (relative) change in the quality score. A regression analysis indicates that the price/quality index is

lowered when independent scoring rules are used, suggesting a lower correlation between price and quality under the independent scoring rule than under the interdependent scoring rule. This result would then be in line with the more aggressive bidding under the independent scoring rule. Koning and Meerendonk (2014) assess the effect of altering the scoring weights of the award criteria in the procurement of public services to reintegrate groups of unemployed and disabled workers in the Netherlands. They find that increases in the quality weights lead to higher bid prices and reduced competition. However, prior to bidding, suppliers were only informed about the scoring weights attached to the award criteria, and not about the scoring method applied. Using data from 382 tenders, Stilger *et al*. (2015) simulate, in a pairwise comparison of 27 different scoring formulas, the frequency by which a pair of two formulas rank the same bid as the best bid. Their simulation shows that the similarity in ranking the same bid as the winner, across the 351 pairs of scoring rules, ranges from 62% to 100%. They also simulate how the weighting of price and quality within 26 different scoring formulas affects the ranking of two bids, a low price/quality bid and a high price/quality bid. Four sets of bids are used, where the two bids in each set vary in terms of their relative differences in price and quality. Each bid is assigned a quality score between zero and one. For every scoring formula, a lowest price-weight is calculated at which the high price/quality bid is ranked as the best bid ("tipping point"). Their simulation shows that some formulas awards a contract to the low price/quality bid relative the high price/quality bid already when the price is weighted at 10%-15%.

In terms of issued analyzed, our study resembles the paper by Albano *et al*. (2008), but we extend our empirical analysis, providing estimates of the Spearman's rank order correlation coefficient of price and quality, using a larger data set from Swedish public procurement. We illustrate the inherent incentives for the buyer to distort his true assessment of the quality dimensions of submitted bids within an interdependent scoring rule, once he has information about the bid prices.

3. Theoretical considerations

To simplify our analysis, we follow Che (1993) and Branco (1997) and let all the nonmonetary characteristics included in the scoring rule to be aggregated into one unidimensional variable q, referred to as quality.

Using a subscript, we order the buyer's assessment of quality level and the price level for a set of submitted bids as $\underline{q} < q_1 < q_2 .... < q_n$ and $p_1 < p_2 .... < p_n < \overline{p}$. Prior to bidding the buyer has declared a both a lowest acceptable quality level, $\underline{q}$, and a reservation price $\overline{p}$. The buyer's value function of *q* is denoted $v(q)$ where $v'(q) > 0$ and $v''(q) < 0$. The buyer's utility is $u(q, p) = v(q) - p$

There exists a configuration (p_i, q_i) such that

$$u_0(p_1, q_1) < u_1(p_2, q_2) = u_1(p_2, q_2) = u_1(p_3, q_3) ... = u_1(p_n, q_n) \quad (1)$$

Let $S = S(q, p)$ denote the scoring rule for an offer (p, q). Again, there exists a configuration (p_i, q_i) such that

$$S_0(p_1, q_1) < S_1(p_2, q_2) = S_1(p_3, q_3) = S_1(p_4, q_4) ... = S_1(p_n, q_n) \quad (2)$$

Independent Scoring Rules

We assume that the buyer's preferences are reflected in the scoring rule and we restrict ourselves to only consider a general quasi-linear scoring rule, that is,

$$U(p, q) = S(p, q) = v(q) - p \quad (3)$$

where $v(q)$ denotes the value of quality. Quality is transformed into a monetary value and the bid generating the buyer the highest surplus is awarded the contract.

Interdependent Scoring Rules

We consider three interdependent scoring rules, where the scoring of the price in each rule is a function of the own price *p* and the lowest submitted price p_1. One scoring rule (*a*) is nonlinear in the price whereas the other two (*b*-*c*) are linear in the price

$$a)\quad s^j\left(p_1,\left(p^j,q^j\right)\right)=\frac{p_1}{p^j}\times k\times\alpha+q^j\times(1-\alpha) \tag{4}$$

$$b)\quad s^j\left(p_1,\left(p^j,q^j\right)\right)=\left[1+\left(\frac{p_1-p^j}{p_1}\right)\right]\times k\times\alpha+q^j\times(1-\alpha) \tag{5}$$

$$c)\quad s^j\left(p_1,\left(p^j,q^j\right)\right)=\left[k-\left(\frac{p^j-p_1}{p_1}\right)\right]\times\alpha+q^j\times(1-\alpha) \tag{6}$$

where k is a constant and α is a weight *[0,1]*

There exists a lowest "equilibrium price" p_1^* and a configuration $\left(p_i,q_i\right)$ such that

$$S_0\left(p_1^*,\left(p_1,q_1\right)\right)<S_1\left(p_1^*,\left(p_2,q_2\right)\right)=S_1\left(p_1^*,\left(p_3,q_3\right)\right)=S_1\left(p_1^*,\left(p_4,q_4\right)\right)...=S_1\left(p_1^*,\left(p_n,q_n\right)\right) \tag{7}$$

Assume that the lowest submitted price in the auction, $\boldsymbol{p_1}$, deviates from p_1^*.

For the non-linear scoring rule *a*) we then have

$$p_{1:n}<p_{1:n}^*\Rightarrow S\left(p_{1:n}^*,(p,q)_{1:n}\right)<S\left(p_{1:n}^*,(p,q)_{2:n}\right)<S\left(p_{1:n}^*,(p,q)_{3:n}\right)...<S\left(p_{1:n}^*,(p,q)_{n:n}\right) \tag{8}$$

$$p_{1:n}>p_{1:n}^*\Rightarrow S\left(p_{1:n}^*,(p,q)_{1:n}\right)<S\left(p_{1:n}^*,(p,q)_{2:n}\right)>S\left(p_{1:n}^*,(p,q)_{3:n}\right)...>S\left(p_{1:n}^*,(p,q)_{n:n}\right) \tag{9}$$

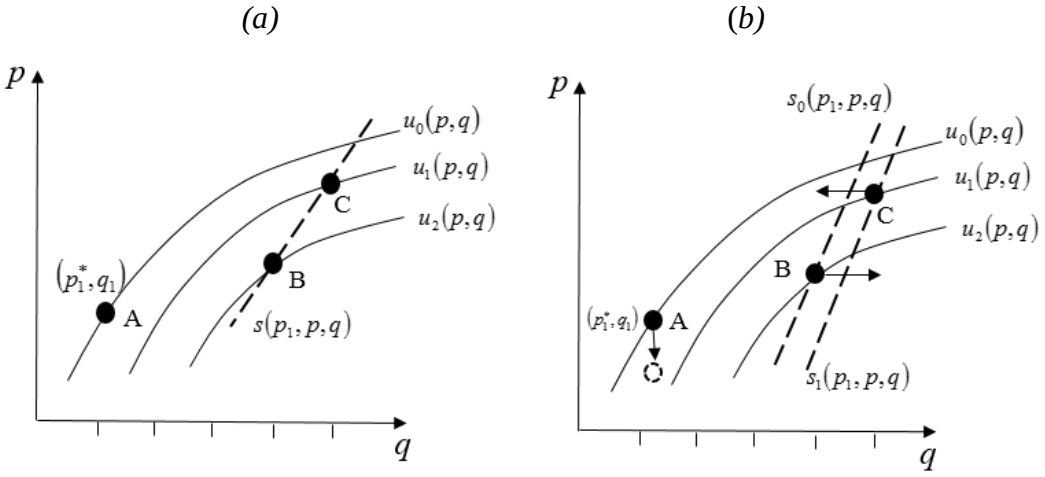
As the price of the irrelevant alternative decreases, the difference in price score between the other bids also decreases, which favors bids with higher quality score. The opposite effect occurs as the price of the irrelevant alternative increases. Similar properties are inherent in the two linear scoring rules *b*) and *c*), albeit the reversed effect upon ranking when $\boldsymbol{p_1}$ deviates from p_1^*. Hence, the purpose of the "policy" parameter α - to convey information about the buyer's preferences for price and quality - is lost. An example illustrates the impact of the irrelevant alternative and the buyer's incentive to misrepresent his preferences when the scoring the quality. Consider the bids A, B and C, which are perfectly correlated in price and quality, $\left(p_1^A,q_1^A\right),\left(p_2^B,q_2^B\right),\left(p_3^C,q_3^C\right)$. The buyer's preferences for the three bids are $u_A\left(p_1,q_1\right)<u_B\left(p_2,q_2\right)>u_C\left(p_3,q_3\right)$ and from eq (7) we have

$$S_0\left(p_1^*,\left(p_1^A,q_1^A\right)\right)<S_1\left(p_1^*,\left(p_2^B,q_2^B\right)\right)=S_1\left(p_1^*,\left(p_3^C,q_3^C\right)\right) \tag{10}$$

Figure 1 illustrates the preferences and the scoring of the bids in terms of an iso-score curve $s(p_1,p,q)$. Whereas the price score is a continuous variable, we assume that the quality

score is a discrete integer variable. Now, should the lowest price p_1 deviate downwards from p_1^*, then, according to the scoring rule, the buyer should select bid *C* as the winning bid. However, since bid *B* is preferred to bid *C*, the buyer has an incentive to misrepresent his assessment of quality by raising the quality score of bid *B* alternatively lower the quality score of bid *C* or a combination of both.

Figure 1. Preferences and the scoring of bids



Of course, the buyer's deliberate adjustment in quality score hinges on some assumptions. First, the buyer is by legislation forced to reveal the price of each bid after having announced the outcome of the procurement, or even prior the evaluation of the submitted bids. Hence, there is no option for the buyer to instead cheat on the prices. Second, the buyer is assumed to have information about the submitted prices of each bid, before evaluating the quality. Third, and perhaps most important, the buyer must be almost in sole control of the assessment of quality. If the scoring of quality is based on standards or properties (certificates, warranties, delivery time, etc.) which are observable and recognized by both parties, and less on arbitrary judgements of various attributes, then the buyer is bound to abide the impact of the lowest price upon the ranking of bids.

4. Data and Analysis

The data set used for this study is collected from Swedish public procurements carried out during the period 2006-2016. In total we have 1 927 bids submitted in 441 tenders. The data only contains tenders with multidimensional bids, where the bids in each tender either have been scored by means of an interdependent scoring rule (price is assigned a score) or having been "monetary" scored according to an independent scoring rule (quality is assigned a monetary value). Roughly, the data set consists of two parts. The first part, covering the years 2006-2008, have previously been used in Bergman & Stake (2015), a statistical study on how public procurements are conducted in Sweden. This data consists of documents and scorecards taken from a random weighted sample of Swedish governmental agencies, municipalities and counties. The second part of the data set, covering the years 2010-2016, are bids and quality scores collected from a Swedish commercial register of public tenders, provided by the firm Visma Commerce. The earlier data from the second part (2010-2013) are mostly from the procurement of consultancies, car leasing, alarm services and minor construction whereas the recent data (2015-2016), are collected in time order.

Table 1 illustrates the distribution of the 441 tenders over time periods, average number of bids and the type of scoring rule applied. We make use of the Common Procurement Vocabulary (CPV) code, used within the EU and assigned to every tender to distinguish between the procurements of services and those of goods/constructions.[5] The last column in Table 1 shows the share of tenders coded with a CPV-code in the interval 50000000 – 99000000, which are tenders comprising mainly services.

Table 1. The distribution of collected tenders across time periods

Period	Number of tenders	Average number of bids	Type of scoring rule			Share of services
			Interdependent	Independent	Not defined	
2006 - 2008	224	4.34	202	22	-	0,58
2010 – 2013	108	4.14	68	38	2	0,61
2015 – 2016	109	4.66	44	65		0,56

4.1 The observed correlation between price and quality

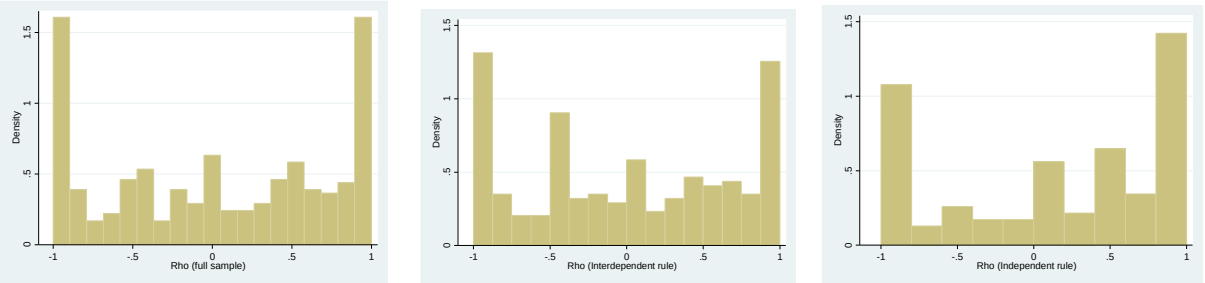
We analyse the observed relationship between price and quality by estimating the Spearman's rank correlation coefficient (*rho*) for each of the 441 tenders. In figure 1 we illustrate the

[5] The CPV code system is a classification system for public procurement used within the EU to describe the subject of procurement contracts.

estimated distribution of the Spearman's coefficient for the full sample and for the subsamples within each type of scoring rule applied. In 51 tenders a correlation coefficient could not be estimated due to ties in assessed quality.

Figure 2. Estimated distribution of the Spearman's rank correlation coefficient (Rho)

a) Full sample *b) Interdependent scoring* *c) Independent scoring rule*



In Table 2 we provide the estimated statistics of rho. As suggested by the bimodal distributions in figure 2, the estimated mean values of *rho* are very low. However, comparing the mean values of the two subsamples indicates a higher positive relationship between price and quality in the tenders subjected to an independent scoring rule.[6] In order to make use of all bids collected, we have, for the 51 tenders where a value of *rho* could not be estimated due to ties, imputed the value zero. The impact of this imputation (*Adjusted rho*) is a drop in the median value of *rho* in tenders facing an independent scoring rule.

Table 2. Spearman's correlation coefficient

	Mean	Std dev	Median	n
All tenders				
Rho	0.035	0.712	0	390
Adjusted rho	0.031	0.670	0	441
Interdependent rule				
Rho	-0.007	0.696	0	274
Adjusted rho	-0,006	0.648	0	316*
Independent rule				
Rho	0.1333	0.741	0.312	116
Adjusted rho	0.124	0.715	0.151	125

*Including the two tenders classified as "Not defined" in table 1

Table 2 shows that the difference in the estimated median value of Spearman's rho across the two types of scoring rules is substantial. The median correlation coefficient is zero in tenders subjected to an interdependent scoring rule whereas it for tenders subjected to an independent

[6] A t-test of mean values generates a t-ratio of 1.78

scoring rule takes a moderate value around 0.3. This magnitude of the correlation between price and quality has also been found in empirical studies of the price-quality relationship in consumer product tests (e.g Steenkamp (1988), Kirchler *et al* (2010))

4.2 Regression on price-quality relation

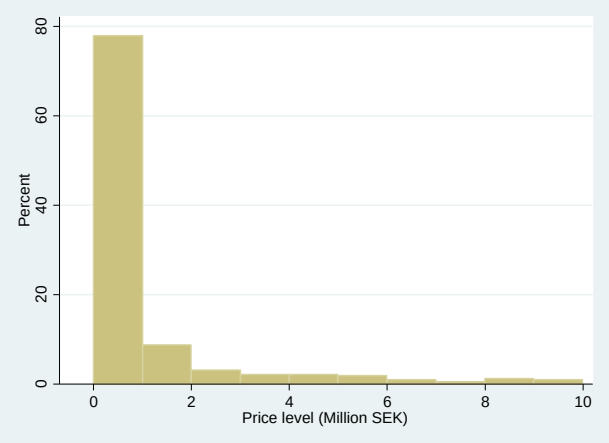
In order to examine how other variables, besides the type of scoring rule, possibly affect the strength of the price-quality relationship, we regress three additional variables on the correlation coefficient. The variables are (*i*) the number of bids (*BIDS*); (*ii*) the price level (*PRICE*) and (*iii*) a dummy variable indicating whether a tender concerns a service or a good (*SERVICE*). We have chosen to make use of the lowest observed bid in each tender to reflect the tender's price level. In Table 3 we provide the descriptive statistics.

Table 3. Descriptive statistics, n=390

Variable	Mean	Std dev	Median	Min	Max	n
Number of bids *(BIDS)*	4.54	3.29	4	2	34	390
Price level *(PRICE)*	7 732 602	8.38e+07	195 546	1	1.64e+09	390
Type of tender *(SERVICE)*	0.59	0.49	1	0	1	390

The estimated mean and median values of the variable *PRICE*, indicate that the distribution is skewed to the right, exhibiting a very long tail. In fact, out of the 390 tenders from which we have obtained an estimate of rho, 283 tenders (72%) have received a (lowest) price not higher than one million SEK. In figure 3, we illustrate the distribution of *Price* for values up to SEK 10 million, in total 358 observations.

Figure 3. The distribution of PRICE for values <10 000 000 SEK



We run regressions on two sample sizes, where one sample includes all 390 tenders. In order to reduce the impact from tenders with an extreme price level, we also analyse a sample which excludes the 32 tenders having an observed lowest bid not higher than SEK 10 million. As can be seen in Table 4, the exclusion of these extreme values has very little influence on the statistics of the other two variables.

Table 4. Descriptive statistics, n=358

Variable	Mean	Std dev	Median	Min	Max	n
Number of bids *(BIDS)*	4.60	3.40	4	2	34	358
Price level *(PRICE)*	879 651	1 797 647	141 773	1	9 990 950	358
Type of tender *(SERVICE)*	0.60	0.49	1	0	1	358

The regression equation is specified as

$$Rho_i = \alpha_i + \beta_1 \times SCORING_i + \beta_2 \times PRICE_i + \beta_3 \times BIDS_i + \beta_4 \times SERVICE_i + \varepsilon_i$$

where *SCORING RULE* and *SERVICE* are dummy variables indicating type of scoring rule applied in tender *i* (1= independent rule) and for type of tender (services =1). The regression results are presented in Table 5

Table 5. Regressions results (std error in parenthesis)

	n=388		*n=356*	
Variable	Model 1a	Model 1b	Model 2a	Model 2b
SCORING RULE	0.153*	0.148*	0.195**	0.189**
	(0.079)	(0.079)	(0.083)	(0.083)
PRICE	6.38e-10	6.11e-10	-3.78e-08*	-3.67e-08*
	(4.30e-10)	(4.29e-10)	(2.12e-08)	(2.09e-08)
BIDS	0.009		0.007	
	(0.011)		(0.011)	
SERVICE	-0.061		-0.066	
	(0.074		(0.078)	
CONSTANT	-0.023	-0.018	0.021	0.014
	(0.076)	(0.043)	(0.083)	(0.048)
Prob > F	0.161	0.076	0.072	0.022
r^2	0.017	0.013	0.024	0.021

Std error in parenthesis

The outcome of the regressions indicates a stronger relationship between price and quality in tenders applying an independent scoring rule rather than an interdependent scoring rule, albeit statistically weaker when including the tenders with a price level above SEK 10 million. Given the smaller sample, the reported coefficient for *PRICE* in Table 5, suggests a weaker price-quality relationship as the price level in tenders increases.

4.3 Are Contracts Awarded to Bids with the Lowest Price?

In this section we investigate the probability that the multidimensional bid with the lowest bid price is the winner of the tender. The analysis is carried out separately on the same two subsamples used when estimating the Spearman's rank correlation coefficient. The first subsample contains the tenders subjected to an interdependent scoring rule. The tender's lowest submitted bid price has been chosen as the reference value against which every other bid price in the tender has been compared and assigned a weighted score [0,1]. Given a set of submitted price-quality bids, monotonically increasing in both dimensions, a higher weight for price, favours bids with lower price-quality combinations whereas a low weight for price encourages firms to aim for high quality. The second sample contains the tenders subjected to an independent scoring rule, where the buyer discounts the bid price with a monetary value for quality. The buyer's preferences for quality relative price is indicated by the buyer's choice of monetary valuation for different levels of quality. In both samples we observe a number of tenders with multiple winning bids. This is mainly due to the procurement of framework agreements in which normally several suppliers are listed as the designated winner. As observed in Table 6, the fraction of tenders, in which the bid with the lowest bid price is awarded the contract, is about two thirds in both subsamples, when adjusting for the tenders with multiple winners.

Table 6. Number of tenders won by the bid with the lowest bid price

Sample	*N* (*a*)	Tenders with multiple winners (*b*)	*n* (*a*) – (*b*)	Lowest price is winning bid among *n* tenders
Interdependent scoring	314	34	280	188 (67%)
Independent scoring	125	18	107	70 (65%)

To analyse factors that might influence whether the bid with the lowest bid price wins the contract, we apply a probit regression model on each sample, where the lowest observed bid price in a tender is our response variable (y), taking on the value 1 if the bid is a winning bid and zero otherwise. Three of the predictor variables we use in both regressions are identical to the variables used in the previous regression analysis on Spearman's rho; the tender's price level (*PRICE*), the number of bids in the tender (*BIDS*) and a dummy variable indicating type of tender (*SERVICE*). In addition, we use a dummy variable to indicate if the lowest bid is among one of several winning bids in tender *i* (*MULTIPLE).* In the regression analysis of the sample of tenders where a weighted score method has been applied (the "interdependent

sample"), we include the size of the buyer's announced relative weight parameter for price as a predictor variable (*WEIGHT*).[7] Again, to reduce the impact from the tenders with an extremely high price level, we exclude in both regressions the tenders with a price level above SEK 10 million.[8] The regression equation is specified as

$$y_i = \alpha_i + \beta_1 \times WEIGHT_i + \beta_2 \times MULTIPLE_i + \beta_3 \times PRICE_i + \beta_4 \times BIDS_i + \beta_5 \times SERVICE_i + \varepsilon_i$$

The outcome of the regressions analyses are presented in table 7.

Table 7. Regression result, probit estimation

	Sample	
Variable	Interdependent	Independent
WEIGHT	2.209***	-
	(0.476)	
MULTIPLE	0.746**	1.507***
	(0.288)	(0.521)
PRICE	1.51e-07**	1.83e-07**
	(6.25e-08)	(9.21e-08)
BIDS	-0.099***	-0.174***
	(0.031)	(0.066)
SERVICE	0.125	0.263
	(0.179)	(0.273)
CONSTANT	-0.433	0.608*
	(0.317)	(0.321)
n	292	112
Prob > chi2	0.0000	0.0021
Pseudo r^2	0.148	0.117

The regression analysis on both samples, generates about the same results. The significant coefficient *PRICE* indicates that the probability for the bid with the lowest bid price to win the tender, increases as the value of the tender goes up. Conversely, the significant coefficient *BIDS* shows that increased competition reduces the probability for the lowest bid price to win the tender. Hence, the value of increased competition seems to be a push up of quality rather than a push down of price. As expected, the coefficient for the dummy variable *MULTIPLE* is positive significant. If more than just one bid in a tender is selected as a winning bid, then the bid with the lowest bid price is likely to be one of them. Equally expected, the regression analysis on the sample comprising the tenders with a weighted score method (interdependent scoring rule), shows that a higher relative weight for price increases the probability that the bid with the lowest price is awarded the contract.

[7] Descriptive statistics of the variable *WEIGHT* and *MULTIPLE* are presented in appendix
[8] See appendix for the regressions results when including the tenders with extremely high price levels

5. Summary

In this paper we have analysed the correlation between price and quality in multi-dimensional public procurement auctions. Our empirical analysis is based on data from Swedish public procurement auctions, spread over the years 2006-2016. In our sample of collected tenders, we can distinguish between two types of scoring rules applied at the ranking of the bids. About 30% of the tenders in our sample, have used a type of scoring rule, which is referred to as an independent scoring rule. Though not necessary for being classified as an independent scoring rule, the common characteristic with the scoring rules in these tenders is that the buyer transforms the quality dimension of the bid into a monetary valuation, which is discounted from the offered price. The bid with the lowest discounted price wins the contract. The bids in the majority of our tenders are ranked with a second type of scoring rule, labelled interdependent scoring rule. The buyer assigns both the bid's quality dimension and the bid's price a weighted score, where the score assigned to price depends on the value of the lowest submitted price in the tender. The bid with the highest total weighted score wins the contract.

The empirical relationship between price and assessed quality across tenders is analysed by estimating the Spearman's correlation coefficient (*rho*) .The analysis shows that the correlation is higher in tenders applying an independent scoring rule than in those tenders subjected to an interdependent scoring rule. Looking only at the tenders from which we have obtained an estimate of rho, we see that the estimated median correlation coefficient is zero for the tenders using an interdependent scoring rule whereas the estimated median correlation is around 0.30 in tenders using an independent scoring rule. The later estimated correlation is in line with results found in empirical studies of the relationship between price and quality in consumer product tests (Lunander *et al.* (2017)).

The observed differences in the price-quality correlation across the two types of scoring rules are likely to be partially explained by the difficulties of the suppliers to adequately capture their offered quality levels in their prices when subjected to an interdependent scoring rule. As an additional explanation, we have developed a simple model to investigate the buyer's incentives to commit to his scoring rule when he applies a relative weighted score method, where the score assigned to each price in the tender depends on the value of the lowest submitted price in the tender. Due to the impact of an inferior price upon the scoring of the other prices, there might exist another bid in the tender, which better matches the buyer's preferences, than the winning bid, designated by the scoring rule. If the buyer is omnipotent when assessing the quality dimension in each bid, he has an incentive to adjust the quality scores such that a desired ranking

of the bids is obtained. This adjustment will then in be reflected in terms of a lower observed correlation between price and quality.

Our empirical findings also indicate that increased competition in multidimensional procurement auctions reduces the probability of the bid with the lowest price to be the selected winner. The expected benefit of increased competition in our auctions seems to be manifested in improved quality rather than in lowered prices.

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Appendix

Table A1. Descriptive statistics, price weights and multiple winners

Variable	Mean	Std dev	Median	Min	Max	n
Price weight	0.519	0.196	0.5	0.1	0.9	314
Multiple winners						
- Interdependent scoring rule	0.108	0.311	0	0	1	314
- Independent scoring rule	0.144	0.353	0	0	1	125

Table A2. Regression result, probit estimation

	Sample	
Variable	Interdependent	Independent
WEIGHT	2.298***	-
	(0.445)	
MULTIPLE	0.640**	1.453**
	(0.285)	(0.517)
PRICE	-1.60e-09	6.28e-08*
	(1.41e-09)	(3.80e-08)
BIDS	-0.105***	-0.179***
	(0.031)	(0.065)
SERVICE	0.054	0.309
	(0.170)	(0.262)
CONSTANT	-0.264	0.697**
	(0.299)	(0.299)
n	312	125
Prob > chi2	0.0000	0.0005
Pseudo r^2	0.135	0.126