

**PROMOTING ECONOMY: ELECTRONIC REVERSE
AUCTIONS UNDER THE EC DIRECTIVES ON PUBLIC
PROCUREMENT**

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ABSTRACT. The reverse electronic auction is a new competitive bidding procedure adopted by the recently enacted European Community (EC) directives on public procurement. It is submitted that the electronic reverse auction has the potential to reduce the tension between the European Commission and national policies of procurement, as it can decrease contracting costs, increase transparency and achieve better economic outcomes as a result of increased competition. This paper relies on auction theory in order to support such statements. A comparison between the traditional sealed-bid method and the reverse auction is further provided.

INTRODUCTION

Public procurement can be defined as the supply chain system for the acquisition of all necessary goods, works and services by the state and its organs when acting in pursuit of public interest (Bovis, 1998, p. 11). In order to perform their legal duties, most governments in western countries resort to the ordinary markets and procure via means of contractual arrangements in order to meet their needs.¹ A recent report conducted by the European Commission (EC) estimates total public procurement in Europe in the year 2002 as amounting to €1.5 trillion, representing 16.3% of the Union's GDP.²

Public procurement was identified as a key obstacle to intra-EU trade in the European Commission's (1985) White Paper, "Completing the

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Internal Market.” The paper dedicated a substantial size of the report to public procurement and highlighted it as “one of the most evident barriers to the achievement of a real internal market” (European Commission, 1985, p. 23). Despite the enormous progress of economic integration in Europe since then³ and the establishment of the internal market, recent empirical data suggests that direct cross-border procurement in Europe accounts for only 3% of the total number of bids submitted by the sample firms, and no more than 30% of indirect cross-border penetration (i.e., foreign firms using local subsidiaries) (European Commission, 2004, p. 2).

Against this background, the legal discussion on public procurement in the EU focuses primarily on ways and means to dismantle preferential purchasing patterns of member states in order to open up the market for effective competition between entrepreneurs without fear of discrimination on grounds of nationality. Transparency and equal treatment in public procurement play a central role in the effort to establish the single market, as envisaged by the Treaties of Rome and Maastricht. The directives on public procurement, adopted in order to achieve these targets, are based on principles such as community-wide advertisement of contracts, the banning of discriminating technical specification, and the requirement that contracts will be awarded on the basis of objective criteria. The latter is achieved through the application of commercial criteria such as value for money, efficiency and competitiveness. However, from the EC’s perspective, these alone are not objectives of the directives (Arrowsmith, 2002).

On March 31, 2004, after extensive consultations with contracting authorities and businesses, the European Parliament and the Council have adopted a new legislative package on public procurement, which aims at modernizing, simplifying and rendering more flexible the existing legal framework.⁴ The directives, which follow the debate launched by the 1996 Green Paper on public procurement (European Commission, 1996), try to mitigate the developing tension between the Commission’s goals to support non-discrimination, transparency and openness of procurement procedures which has been done by complex and rigid procedures- and the quest of contracting authorities at the national level to promote commercial and non-commercial policies such as efficient procurement process, value for money, and social or environmental considerations.⁵

One of the fields in which the new directives adapt to modern administrative needs is the use of information and communication technologies and the adoption of fully-fledged electronic procurement. The new directives have recognized the advantages of using electronic auctions as means to allocate contracts in a more efficient and transparent way and have adopted specific rules governing the use of such a procedure.

Economic theory suggests that, if used properly, auctions have the potential to improve value for money, efficient allocation of resources, and transparency in the process of awarding contracts. This paper is an attempt to shed additional light on the advantages of auctions as a means to award contracts. This is done by studying economic theory, which treats auctions as games with incomplete information, in which players make rational and strategic decisions, depending on decisions made by all other players. A comparison between the electronic auction and the traditional procedures is also provided.

COMPETITIVE BIDDING AND EC PUBLIC PROCUREMENT POLICY

Interestingly, almost all national, regional and international regulations of public procurement use the same procedural regime to govern procurement practices, which is the requirement to conduct competitive tendering. At state and local levels, competitive bidding is used to provide the public with low-priced, high-quality contracts, to fight corruption, and to provide equal opportunities to all firms to enjoy the benefits of a contractual relationship with the government. One of the main objectives shared by most national public procurement systems is 'value for money,' which requires that contracts be awarded to tenderers who offered best terms of contracting possible. This, of course, does not mean that a contract should be always given to the tenderer who offered the lowest price, but rather that the total evaluation of all elements which compose the offer would be the most suitable for the authority's requirement and would be the most favourable in terms of cost and quality evaluation. Competitive bidding plays an important role in pursuing value for money, as it has the capability to generate competition on the supply side and thereby allow contracting authorities to enjoy, at least in some cases, a monopsonistic position.⁶

At the European level, public procurement is first and foremost subject to the general provisions of the EC Treaty, such as the four

fundamental freedoms,⁷ the prohibition of discrimination on grounds of nationality,⁸ and the freedom of establishment.⁹ These provisions are concerned with in assuring non-discrimination and equal treatment to all potential contractors,¹⁰ thus forbidding arbitrary distinction between different groups within the EC.

Since the EC Treaty does not deal directly with public procurement, more specific regulation was needed. The EC's first attempts to regulate public procurement were made in the early 1960s. Since then, three generations of regulations have been adopted, the last of which was in March 2004.¹¹ The main tools used by the public procurement directives to promote the principles of equality and non-discrimination on grounds of nationality are transparency, publicity, restrictions on discretion and a ruled-based decision making mechanism, above all, competitive bidding.

Although competitive bidding is used to promote both EC and national objectives in public procurement, the scope and methods of its application on the various levels have been a source of potential conflict (Arrowsmith, 2002). As explained above, from the EC's perspective, competitive bidding merely aims at opening up the market to intra-European trade. On the national level, however, strict formalities of competitive bidding and narrow methods of application as set by the European directives have hazarded national objectives of pursuing best value for money. One indication of the tension between the EC and national policies is the fact that contracting authorities very often use the restricted procedure (in which only selected suppliers are invited to submit proposals) rather than the open procedure. The latter has the potential to guarantee that all interested parties are invited to submit bids, thus serving the EC's goal of opening up the market. The former decreases administrative and evaluation costs, thus allowing contracting entities to conduct a more cost-effective process. Moreover, the use of competitive bidding under the European directives did not permit --in principle -- the use of alternative bidding procedures other than the sealed-bid tendering until recently. Whereas private companies and businesses have witnessed a rapidly expanding array of technology options for strategic sourcing and procurement, contracting authorities subject to the directives were bound to use only the single stage traditional tendering procedure, which in many cases did not prove to be the most economically justified.

In attempts to mitigate the increasing tension between the Commission and national policies, and with a view to modernize the

legal framework on public procurement, the Commission adopted in March 2004 a new legislative package which aims at modernizing, simplifying and rendering more flexible the existing legal framework on public procurement. Realizing the increasing popularity of the use of information and communication technologies in tendering procedures in private markets, and the potential of the use of auctions to exert a positive effect on competition, the Commission adopted a fully fledged electronic procurement procedure known as the 'reverse electronic auction.'

THE NEW COMPETITIVE BIDDING TECHNIQUE: THE REVERSE AUCTION

The advantages of using auctions as a trade mechanism were recognized a few hundred years ago and have been studied extensively by economists for the last five decades.¹² One of the earliest auctions ever is said to have taken place in the year 193 A.D., when the Praetorian Guard auctioned off the entire Roman Empire. After having killed Pertinax, the Roman emperor, on March 28, 193 A.D., the leaders of the Guard declared that the highest bidder could claim the Empire. Didius Julianus, who paid 6,250 Drachmas per guard, was the first bidder in history to experience 'winner's curse' after losing his new property to Septimus Severus, who conquered Rome only two months later (Cassady, 1967; Klemperer & Termin, 2001).

The newly enacted reverse electronic auction is an increasingly popular tendering process that is commonly used by private companies and businesses to reduce prices in procurement with comparison to other methods. Recourse to the reverse electronic auction enables procuring entities to procure products and services when price is the key award criteria, or in cases when other elements of the tender can be expressed in figures or percentages. In a reverse electronic auction, all suppliers view the auction site (usually via the internet) and follow the progress of the tender as the auction proceeds. Suppliers are required to submit bids and are provided with information on prices submitted by their competitors as well. As the auction proceeds, suppliers are allowed to amend their bids on an on-going basis in competition with other tenderers and to change factors such as the price offered or non-price aspects. Once the time limit is over, the price and non-price aspects are combined to give an overall ranking of bids. The bid that is mostly favorable is then selected.

It has been said that the new electronic auction has the potential to decrease costs of contracting, to increase transparency, and to achieve better economic outcomes as a result of increased competition. Is the new electronic auction really able to bring about such gains? What makes the electronic auction so efficient, and why is it said that it is superior to traditional tendering? The next sections turn to economic theory in order to evaluate these statements.

What is an Auction?

Economic theory defines auctions as a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from market participants (McAfee & McMillan, 1987). Unlike competitive markets in which the price is determined by the market and all firms and sellers are price takers, auctions are characterized by an environment in which several buyers compete to purchase an item from a single seller, and the seller has to determine to whom he wishes to sell the good and at what price. In order to extract the highest revenue, the seller has to identify the buyer that evaluates the item the most, and is hence willing to pay the highest price.

According to economic analysis, there is no distinction between cases in which bidders compete to buy an item from a single seller, and those in which tenderers compete to sell an item, service or work to a single buyer. Obviously, public procurement corresponds to the latter case, in which tenderers compete among themselves for the opportunity to enjoy the benefits of a contractual relationship with the public authority. In the economic analysis, however, there is almost perfect correspondence in the results.

Basic Types of Auctions

Although public contracts are usually awarded by using only one format of tendering, economic analysis of auctions distinguishes among a variety of auction formats, which may be ranked according to the price they yield and their ability to allocate resources efficiently. There are, however, only four primary formats of auctions on which the literature focuses, and most of the analysis refers to one or more of these types or formats. These are the first-price sealed-bid auction, the second-price sealed-bid auction, the Dutch auction, and the English auction.

The First-Price Sealed-Bid Auction Format

In a procurement first-price sealed-bid auction, each supplier independently submits a single bid without seeing the bids of others. Usually, each participant is allowed to submit only one bid, which means that bid preparation is especially important. A sealed-bid format has two successive phases: a bidding period in which tenderers submit bids and a resolution phase in which the bidding box is opened and the winner is determined. The name ‘first-price’ comes from the fact that when a single contract is given, the tenderer who submitted the lowest price (or the most economically advantageous bid) wins the auction and is awarded the contract for the price bid. The first-price sealed-bid auction is the most common and traditional method that is used in most regulations of public procurement.

The Second-Price Sealed-Bid Format

With a procurement second-price sealed-bid format,¹³ the lowest bid submitted merely determines who wins the auction, whereas the actual price is determined by the *second* lowest bid (submitted by someone else), which is by definition higher than the best-submitted price. *Prima facie*, this mechanism seems to be inferior to the first-price auction since the price paid by the contracting authority is higher than the ‘potential price’ submitted. However, the strategy underlying this rule is convincing: given that price is determined by someone else’s bid, tenderers have no incentives to submit a bid above their real evaluation of the costs of the contract. On the one hand, if a tenderer submits a bid which is higher than his private evaluation, he will only reduce his chances of winning and will not change the final price in case of a winning. This is because the final price is not determined by his bid, but rather by the runner-up’s bid. On the other hand, if he submits a bid that is lower than his evaluation, he would increase his chance of winning only in the case that the second lowest bid is lower than his real costs but still higher than his actual bid. In that case, he will win the tender, but will be given a price below his real costs. It is for this reason that the second-price sealed-bid auction induces tenderers to be ‘truth telling;’ i.e., to submit bids which correspond exactly to the best price they are able to offer, hence enabling contracting authorities to screen tenderers according to their potential performance and thereby achieve ‘best value for money.’

The Dutch Auction

If contracting authorities were to use a Dutch auction, it would have been conducted in an overtly manner where an initial price was set that is much lower than any reasonable evaluation. The price then increases by steps until the first tenderer indicates his intention to sell at the price level reached, in which case he is declared the winner. Tenderers in a Dutch auction therefore face a dilemma: on the one hand, the sooner a tenderer indicates his willingness to sell, the lower the price he gets. On the other hand, if he waits too long, another tenderer might jump in before and win the auction. A tenderer's strategy in a Dutch auction will therefore be to make a bid once the price exceeds his evaluation but is still lower than his expectation of the runner-up's evaluation.

In contrast to the second-price auction, the Dutch auction cannot guarantee best price possible in all cases. However, as will be argued below, it does not necessarily mean that the selling price will be higher on average than any other format.

Another variation of the Dutch auction is conducted in a manner in which the price is fixed in advance and the quantity sold for the price constantly changes (decreases in case of procurement). In a selling Dutch auction, this may be used when several items are offered for sale, for instance, flowers, in which case, the seller sets the initial price and then adds more flowers to the lot until the first buyer accepts the offer.

English Auction

In a traditional selling 'English auction,' tenderers physically congregate in a single location and call out their bids orally so that each tenderer is immediately aware of the bids made by others. A tenderer may bid multiple times as reserve prices are successively raised until only one tenderer remains and no one increases his bid, in which case he is declared the winner and may claim the item at the price he last bid. The English format has the advantage of giving the right incentives to tenderers to be 'truth telling': tenderers participating in the English auction continue to raise their bids up to the point where price exceeds their evaluation. Any bid above their evaluation means loss of money in case of a winning, and therefore they would not do so. Consequently, at the end of the tendering phase, only the tenderer with the highest evaluation will be awarded with the item for a price that is slightly higher than the last bid which was called out. On average, this price will equal

the second highest evaluation, just as in the case of the second-price sealed-bid auction.

The ‘electronic auction,’ provided in the new directives, is nothing else but an English auction, only the request to gather in one room is lifted since bids are ‘called out’ via electronic means of communication. In addition, in procurement auction prices successively drop (instead of rise) and that is the reason why the procurement electronic English auction is usually referred as a ‘reverse electronic auction.’

Auctions and Game Theory

Economic analysis uses game theory to analyze auctions. Game theory is a formal way to analyze interaction among a group of rational ‘players’ who behave strategically, and applies to situations where choices and decisions of one player are partly governed by what he thinks his opponents will do.

Economic analysis of auctions is not able to offer a comprehensive and unified model of auctions that corresponds to all circumstances as may occur in reality. Instead, it provides different models, based on different assumptions, which attempt to reflect specific circumstances that may indeed occur. Indeed, empirical work in the field of auctions, such that will validate theoretical research, is of great importance. Nevertheless, auctions are mechanisms with a specific set of rules that clearly design the market and achieve resource allocation and price formation. This is surely central to economic theory, and for that reason auction theory has witnessed substantial and rapidly growing attention, both in theoretical, and to some extent, empirical work.¹⁴

Criteria for Evaluation of Auction Formats

It is widely accepted that competitive bidding is a method which can best achieve efficiency, cost savings, and most and foremost, equal treatment and transparency. Whilst it is agreed that the use of competitive bidding is the most desirable method of contracting in the public sector, the question as to what form of competitive bidding should be engaged has been left almost entirely outside of the legal discussion. It was argued above that under the new directives, contracting authorities may choose to conduct competitive bidding in accordance with one of two alternative formats. Given the justification to use competitive bidding, is it possible that one auction format is superior to others?

The economic analysis of auctions has been occupied with this question for the last five decades. Major progress has been made after the clarification of the Bayesian Nash equilibrium by Harsanyi (1967) in 1967, thus applying game theory to analyse auctions. The analysis views auctions as games of incomplete information that are evaluated on grounds of two criteria: efficiency and revenue. An efficient auction is one that puts goods into the hands of those who value them the most, thus fulfilling the social criteria of Pareto efficiency (Dasgupta & Maskin, 2000). When the revenue criterion is met, it is said that the auction is 'optimal,' since it maximizes revenues for the seller.

Contracting authorities, which are interested in obtaining the best value for taxpayers' money on the one hand, and ensuring that contracts are assigned to the most competitive providers in order to guarantee a long-term growth of the market on the other hand, should make sure that the auction format they intend to use corresponds to these two criteria. Since transparency is a central principle in the European regime of public procurement, any comparison among auctions would not be complete without evaluating the degree of information flow that is allowed under each of the auction formats.

BASIC MODELS

In order to understand the results provided by the economic analysis, some basic concepts must be first understood. In the section below, the basic models, each composed of a different set of assumptions, are presented. All mathematical proofs are omitted, and whenever such exist, a reference to their source will be made.

There are several assumptions made with regard to information available for tenderers on the object or project at auction and about other tenderers' bids. In general, it is assumed that tenderers who are considering participating in an auction may face three kinds of uncertainties. The first kind of uncertainty is with respect to the value of the contract in question, thus they may not be sure about the costs of executing a specific work required. The second uncertainty is with respect to the characteristics of the tenderers themselves, for example, whether other bidders are risk-neutral or risk-averse (as will be elaborated on later). The third kind of uncertainty is with regard to the bidding strategies used by other tenderers; i.e., how aggressively they are willing to bid. Since not all uncertainties may occur simultaneously, the

economic analysis uses several models. Each is based on a different set of assumptions as to the information environment in which the auction takes place. Once the ‘tendering conditions,’ or the assumptions to be used, are defined, each auction format is evaluated according to its ability to ‘exploit’ the uncertainties that exist in the specific bidding environment. Thus the analysis aims at examining which auction format, under the given information structure, is best able to: (1) stimulate competition among tenderers and thereby yield higher revenues for the seller; and (2) sort tenderers according to their evaluations, thus making sure that the highest evaluator also submits the most competitive bid, hence ensuring efficient allocation of resources. Obviously, in procurement auctions the highest evaluator will submit the lowest or most economically advantageous bid.

For example, the differences in the manner that the English electronic and the first-price auctions are conducted may play an important role if there is uncertainty with respect to the real value of the item or project in question. In the first-price sealed-bid auction, proposals are submitted privately so that bidders are not able to compare their bids to others. In the English electronic auction, on the other hand, bidders are required to submit bids publicly so that other tenderers may immediately learn their rivals’ prices. This may make bidding more aggressive, since after learning their rivals’ bids, tenderers may believe that the project’s value (in terms of expected revenues for the contractor) is actually higher than their initial estimate, and may correct their bids accordingly during the bidding period. From the procuring entity’s point of view, such competitiveness may be exploited to yield better terms of contracting.

On the other hand, if tenderers are risk-averse, it might be wise to exploit tenderers’ fear that someone else might outbid them by a small margin. If, for example, tenders are not certain on their rivals’ bids, it might cause them to submit a more attractive bid just to avoid bearing that risk. Under such circumstances, it is the first-price sealed bid, in which tenders cannot see their rivals’ bids, which yields higher revenues.

In short, the economic analysis is conducted in two phases: first it is important to choose the model which best corresponds to the ‘tendering conditions’ under which the auction is conducted. Only then different auctions may be evaluated according to their ability to maximize revenues for the seller and to yield Pareto efficient results. We begin

with the first phase by presenting the set of assumptions underlying each model.

The Independent Private-Value Model

Under the independent private-value model, two basic assumptions are made (Vickrey, 1961). First, it is assumed that each tenderer has a private evaluation, so that his evaluation of the item is derived only from his own consumption (or performance in cases of procurement contracts). Second, it is assumed that all evaluations are also independent. This means that tenderers' evaluations depend only on their own private estimations and are not affected by estimations of other suppliers. Thus, learning other tenderers' evaluations would not cause a tenderer to revise his bid. In order to facilitate calculations, auction theory assumes that under this model, evaluations are independently distributed according to one commonly known probability function.

A common example associated with the independent private-value model is the auctioning of an art painting for private collectors. When all buyers are interested in purchasing the painting for self-use, evaluations differ among buyers according to the value they attach to the painting as a component in their collection. Hence, each buyer has a different evaluation of the painting, which does not depend on the evaluation that other buyers attach to it.

In a procurement situation, this assumption might best simulate procurement of goods or services that are produced according to different production techniques. For example, a tender for the provision of landscape architectural design services, in which suppliers use variety of techniques and personal skills may entail mainly independent components, so that each supplier may incur different costs, whereas learning other suppliers' evaluations would not cause him to revise his own evaluation.

The Common-Value Model

In contrast to the above, the common-value model simulates situations in which the item for sale has the same value for all tenderers, but each of them has different private information about this value, and at the time of tendering none of them knows for sure what that value is. Furthermore, since the item has the same value for all, tenderers' estimations are perfectly dependent, since by seeing other bids, tenderers

are able to learn more about the true value of the item and revise their own bids accordingly. The common-value model thus assumes one finite 'true' value, which is revealed only after the auction is finished.

The common-value model corresponds to cases where there are uncertainties regarding the cost of factors that are essential for the full evaluation of the contract in question. Under such circumstances, each tenderer's estimation is just an estimate, which is subject to errors, and he has to guess at the time of bidding what would be the true value, without having knowledge about other tenderers' estimations (Capan, Clapp & Campbell, 1971; Oren & Williams, 1975). The best example for the case of the common value model is bidding for offshore oil leasing contracts: tenderers must guess the true value of the leases offered, given high levels of uncertainty with each of the tenderers having access to different fractions of incomplete information about the true value of the lease. Only after the drill rights are given, the true value of the resource will be revealed (Oren & Williams, 1975; Reece, 1979).

The Affiliated Values Model

The independent private value and the common value models describe two extreme circumstances, which may not occur so often in reality. Under the affiliated values model, the independence assumption is relaxed and replaced by the assumption of a positive correlation between tenderers' evaluations (Milgrom & Weber, 1982). It is assumed that in almost any auction, the information available for tenderers consists of both private and common components. Thus, in the case of the art painting that is auctioned to private collectors, it is plausible that the painting will be resold in the future and that the resale price will be the same for all buyers. This of course would add a common-value component already in the first auction. In the offshore oil leasing auction, on the other hand, it might be the case that some companies have superior techniques of extracting oil which enable them to enjoy these rights more than others. Thus instead of having either totally independent or totally dependent evaluations, the affiliated values model assumes that tenderers' evaluations are composed of various parameters, some of which are dependent and others that are independent. In short, under the affiliated values model, tenderers' evaluations of the item for sale only partially depend on some common random components, and high valuations by other tenderers make it more plausible that a specific tenderer will value the item higher as well.

COMPARING AUCTIONS

The Benchmark Model

Under which auction format is a contracting authority best able to pursue its objectives? The first result that auction theory provides is quite surprising: all auction formats yield on average the same selling price and allocate the item to the same tenderer, who values it the most. This result, which is called 'the revenue equivalence theorem' (Myerson, 1981) is based on the independent private-value model, and includes the following additional assumptions: (1) All tenderers are risk-neutral; (2) all tenderers are symmetric; (3) tenderers' payment depends only on their bids; (4) royalties, incentives and payments for quality are excluded; (5) the auction is for indivisible one-unit only; and (6) all tenderers behave competitively and any possible collusion among tenderers is excluded (McAfee & McMillan, 1987).

The above set of assumptions composes the so-called 'benchmark model,' which is the easiest to analyse due to its straightforward assumptions. The equivalence among all auction formats, which is the result of the benchmark model, does not mean that the outcome in a first-price sealed-bid auction will be exactly the same as that in the English auction or the second-price sealed-bid auction for instance, but only that on average all auction formats lead to the same equilibrium result. To illustrate, it is worth having a closer look at the strategies underlying tenderers' behaviour under the assumptions of the benchmark model: It is proven that tenderers' strategy in the first-price sealed-bid and Dutch auctions are equivalent (Vickrey, 1961). In both cases, each tenderer faces a similar dilemma: he has to decide how high (or low) he will bid given that no other tenderer has announced his price, thus trading between his probability to win and his expected revenue. The lower the bid submitted, the better the chances of winning, but with lower revenue. This common dilemma makes tenderers' strategy in the first-price and Dutch auctions equivalent. The economic analysis further submits that under the benchmark model, the winning price on the first-price and Dutch auctions is a Nash equilibrium¹⁶ of all tenderers' strategies, and will equal the expectation of the valuation of the second-lowest tenderer (McAfee & McMillan, 1987).

Under the English and the second-price sealed-bid auctions, tenderers have a common dominant strategy¹⁷ to bid their true valuations. It was argued above, that under the second-price sealed-bid auction the

price is determined not by the winner's bid, but rather by the second lowest bid. But this is exactly the result of the English auction: the tenderer with the best evaluation will be awarded the item for a price that equals the bid which was submitted by the last bidder who dropped, i.e., the second lowest bid. This follows from the fact that the second-best evaluator, by definition, has decided not to reduce his bid further, and the winner pays the last price offered, which equals to the second-best evaluation.

It is difficult to identify specific procurement situations that perfectly correspond to the benchmark model. One possible explanation stems from the very simplifying assumptions that underline the benchmark model. In those contracts which correspond to the benchmark model, the choice between the traditional (i.e., the first-price sealed-bid) and the electronic auction (i.e., English auction) procedures has no economic implications since under the benchmark model they will both yield similar results.

It follows that under such circumstances the electronic tendering procedure should be preferred to the traditional tendering procedure due to its clear advantages with respect to transparency. This stems from the fact that under the electronic auction procedure, the danger of having the procuring entity favoring a particular firm by providing it information on other tenders is limited. Under the electronic auction procedure, information on other bids is available to all tenderers in an open and equal manner. Moreover, all bidders are allowed to amend their tender at any time within the limits of the time period. Thus, the electronic auction increases transparency in two levels: (1) information available on other tenders; and (2) the availability of the procedure phases and its outcome to all interested tenderers. Thereby, the electronic reverse auction serves better the goals of the European procurement system.

Dependent Valuations

What happens in cases where there exists a positive correlation among tenderers' evaluations? Recall that this assumption simulates cases in which the contract in question has features that are difficult for assessment; for instance bidding for offshore oil lease contracts where tenderers are not sure about the real value of the contract. In this section, the independence assumption is relaxed and replaced by the assumption of a positive correlation between tenderers' valuations, while all other assumptions remain the same.

The game theoretical analysis of auctions submits that the revenue equivalence theorem does not hold anymore, and auction formats may be ranked according to the price they yield. It is proven that when evaluations are affiliated, the English and second-price sealed-bid auctions are superior to the first-price sealed-bid and Dutch auction formats in terms of revenues for the auction organizer (Milgrom, 1989). The logic behind this result is that due to correlation among evaluations, the difference between the first and second highest bids under the English and second-price auctions is expected to be smaller. For example, under an English auction, the second-highest evaluator will continue to bid even higher than his initial intention since he might be influenced by the high bidding of his competitor.

Further, economic analysis provides that the English auction yields better prices for the auction organizer than the second-price auction, which as argued above, is superior to the Dutch and first-price auctions. The first-price and Dutch auctions yield the same expected price on average. The reason that the English auction will lead to better prices is due to the fact that when tenderers bid publicly, other tenderers are able to purchase useful information by observing their rivals' bids.¹⁸ It is as if the English auction proceeds in two phases. In the first phase, tenderers that drop out 'reveal' their estimations, thus allowing other bidders to purchase valuable information. In the second phase, there are only two tenderers left, and they engage in a second-price auction. The release of the information in the first phase, weakens the effect of the 'winner's curse' (which will be discussed below) and makes the flow of exogenous information easier. The result is that under the English auction, competition is increased as tenderers are encouraged to bid more aggressively (Milgrom & Weber, 1982). In procurement auctions, this means better terms of contracting, hence better value for money.

In the author's view, the dependent valuations model reflects a larger variety of cases that occur in reality than the independent valuations model. In most procurement bidding, tenderers do share common components in the preparation of bids. Evidence to that is the fact that practices such as industrial and business espionage still exist among firms that compete for public contracts, and many enterprises employ underground methods to obtain competitive information on their rivals. Had it been the case of independent valuations, such methods could not have yielded any benefits, and hence would not have been employed. Moreover, in most cases it is unusual to find situations in which firms

competing in similar sectors have totally different costs and production functions, thus share no common market characteristics with other firms from the same sector.

To sum up, economic theory submits that under the affiliation assumption, the English auction is preferred to the first-price auction not only with respect to transparency and information flow, but also due to the fact that it increases competition among tenderers, thus assisting procuring authorities in achieving better value for money.

The 'Winner's Curse'

The extreme case of affiliation occurs when evaluations are perfectly correlated; i.e., the case of the common value model. It was already mentioned, that under this set of assumptions, the true value of the item is uncertain and tenderers' knowledge about it is limited. For that reason, tenderers might make judgmental failures with respect to the value of the item, in which case the item for sale will be awarded to the tenderer who submitted the most overestimated bid, and not to the tenderer who submitted the most 'correct' one (i.e., the bid that reflects the true value of the item). This phenomenon, in which the winner tends to bid more than the expected value of the item, thus the selling price exceeds the true value of the item, is known in the literature as the 'winner's curse' (Oren & Williams, 1975; Capen, Clapp & Campbell, 1971). Evidence to the 'winner's curse' phenomenon can be found both in laboratory auction markets (Kagel & Levin, 1986; Bazerman & Samuelson, 1983; Kagel, 1995) as well as in practice; for instance, in auctions of offshore oil rights (Capen, Clapp & Campbell 1971; Mead, Moseidjord & Sorenson, 1983; Lorenz & Dougherty, 1983), in the book-publishing industry (Dessauer, 1981), in the market for baseball players (Cassing & Douglas, 1980), in real estate auctions (Ashenfelter & Genesore, 1992), and in corporate takeover battles (Roll, 1986).

The 'winner's curse' phenomenon suggests a possibly strong justification for allowing contracting authorities to set aside as abnormally low those tenders offering a discount greater than what seems reasonable.¹⁹ Given the potential for the 'winner's curse,' awarding the contract to the cheapest bid entails the risk that due to wrong estimations, or misunderstanding of some intricate aspects of the project, tenderers' ability to perform the contract in accordance with the requirements of the bid solicitation is in question. Thus, public interest

requires that authorities should be able to reject bids that may be considered too risky. Interestingly, economic analysis further implies that the justification to reject bids as abnormally low exists only in situations that correspond to the common value models, and not in situations that correspond to the independent value model, in which tenderers do not make judgmental errors. The directives provide a solution to this problem by demanding that any rejection of bids as abnormally low is subject to tenderers' right to provide the necessary explanations to those parts that the contracting authority finds unacceptable.²⁰ It follows that when tenderers are not sure about their evaluation (i.e., as under the common value model), they would not be able to meet this requirement since they simply do not have the information needed. Under the independent private value model on the other hand, evaluations are private and tenderers are sure about their capability to perform the contract. Therefore, they will be able to support their bids with sufficient explanations.

There are two main factors that influence the magnitude of the winner's curse (Wolfstetter, 1995). First, the higher the number of tenderers that participate in the auction, the larger the effect of the winner's curse will be. This is simply because the probability of having a higher over-estimated bid is greater when more bids are submitted. The second factor that influences the magnitude of the bias is the amount of information and its accuracy that is available for tenderers prior to the bidding. The less information tenderers have, the larger the 'mistakes' they would make.

By deciding on which procedure to use, contracting authorities may also want to consider the fact that since in the English auction bids are submitted in an open manner, tenderers' private estimations of the item become immediately public. This may reduce the amount of uncertainty and thereby mitigate the effect of the winner's curse (McAfee & McMillan, 1987, p. 722). To that extent, the English format is less vulnerable and therefore preferable in cases of common value auctions. In any event, the demand to provide necessary explanations for abnormally low bids is an efficient mechanism to eliminate bids that might be subject to the winner's curse phenomenon.

Risk Aversion and Asymmetry

In this section two additional assumptions, which underlie the benchmark model, are relaxed. First, the assumption of risk-neutrality is

relaxed, leaving the assumption of symmetry among tenderers. Then the case of asymmetric tenderers is discussed, and a comparison among auction types is conducted.

Risk Aversion

The degree of risk aversion²¹ in auction theory represents the extent to which tenderers try to avoid the uncertainty related with the outcome of the auction. In procurement auctions, a 'risk-averse' tenderer will prefer to submit a lower bid, albeit having a lower revenue in case of a triumph, in order to increase his probability to win the auction.

To what extent are contracting authorities able to exploit the fact that tenderers competing in a procurement auction are risk averse? Economic models submit that the first-price and Dutch auctions, given that valuations are symmetric and independently distributed, will yield higher average selling price when tenderers are risk-averse (Maskin & Riley, 1984). This is due to tenderers' tendency to submit higher bids in order to increase their chances of winning, thus increasing their utility for a lower but safer income. In contrast, risk aversion does not change tenderers' bidding strategy in the second-price and English auctions. This is because tenderers' best and dominant strategy remains to be 'truth telling;' i.e., submit bids which equal their true evaluations (Maskin & Riley, 1985). It follows that the first-price and the Dutch auctions have the potential to yield better results from a price determination point of view in comparison to the second-price and English auctions (Maskin & Riley, 1984).

In addition, if contracting authorities are considered to be risk-neutral, they are able to increase their profits further in a first-price auction if they subsidize low tenderers who lose and 'penalize' tenderers who submitted high bids. Charging a bidding fee that is an increasing function of the bid can be used for that purpose (Maskin & Riley, 1984). However, it is doubtful that the use of such a technique is compatible with the European directives, since charging differential bidding fees may harm the principles of non-discrimination and equal treatment, which are central to the European regulation of public procurement.

The application of the risk aversion assumption to reality is again relatively complicated. Potential tenderers in procurement procedures may be composed of public-held corporations, entrepreneurs, family-held companies, and in some cases private individuals. The degree of

risk aversion exerted on bidders may depend on the diversification of their investments, or alternatively, the investments of the firm's shareholders. Obviously, in projects which are characterized by participation of small and medium-sized firms,²² the degree of risk aversion may be higher than in the case of competitive bidding among publicly held corporations with diversified portfolio. In such cases, the traditional procurement procedure (i.e., first-price sealed-bid auction) may be preferred to the electronic auction procedure from a revenue point of view.

It was mentioned above that under the assumptions of the affiliated values model, auctions are ranked in exactly the reverse preference structure, i.e., English is preferred to the second-price auction, which is preferred to the first-price auction. Thus, the first-price auction with risk-averse bidders is preferred to the English auction only when the assumptions of the independent private value model hold. Under the affiliated values model and with risk-averse tenderers, the ranking of auctions is not so clear and mainly depends on the degree of risk aversion of the bidders.²³

Asymmetry

Economists make further assumptions with respect to how tenderers evaluate the item in sale. In order to facilitate calculations, auction theory assumes that evaluations are randomly assigned to tenderers, and these values are drawn from a statistic distribution function. If there is only one distribution function from which evaluations are 'drawn,' it is said that tenderers are symmetric. Whenever there are more than one distribution functions from which evaluations are drawn, tenderers are said to be asymmetric. Thus under the assumption of asymmetry, it is possible that two tenderers will submit different bids although they have the same evaluation.²⁴

The asymmetry assumption best simulates situations in which tenderers have different production costs, so that some have comparative advantage in comparison to others. Such asymmetries among tenderers may be the result of different backlog capacities, technology, location, size, or different access to information. The asymmetry assumption is therefore often used to assess international public procurements, where both domestic and foreign companies compete.

The economic analysis suggests that when tenderers are asymmetric, the second-price sealed-bid and the English auctions are Pareto efficient, whereas the first-price and Dutch auctions are not. The inefficiency in the first-price and Dutch auctions stems from the fact that in some cases, the item in sale might be allocated to a tenderer who is not the highest evaluator, despite the fact that he submitted the most competitive bid (Krishna, 2002). The reason for this inefficiency is that tenderers, who draw their evaluations from different distribution functions, might estimate differently the amount of competition they face from other tenderers. Such a distortion is not likely to occur in second-price or English auction formats. In both cases, as already mentioned, tenderers' dominant strategy is to bid their true valuation no matter what. This tendency holds also when tenderers are not symmetric anymore hence Pareto efficiency is guaranteed (Milgrom & Weber, 1982; Wolfstetter, 1995).

With respect to revenues, auction theory is not able to provide a decisive answer as to which type of auction yields the highest revenue when tenderers are asymmetric. Some economists argue (Maskin & Riley, 2000; Krishna, 2002) that in many cases the first-price auction will yield higher revenues than all other types of auctions, but in some other cases, it is the English or the second-price formats that will maximize the seller's profits. When the assumptions of the common value model apply, it is the second-price auction that yields a better price than the English auction (Krishna, 2002).

To sum up, when tenderers are asymmetric, such as in cases of heterogeneous tenderers, or in international procurement, a contracting authority is able to yield efficient allocation of resources if it conducts either a second-price or English auction. These auction formats will also yield higher average revenues than the first-price auction under the assumptions of the common value model.

Collusion

Collusion can be defined as an arrangement among a group of bidders, either explicit or implicit, that is designed to restrict competition (Porter & Zona, 1993). As a result, contracting authorities might face higher prices and the members of the cartel will enjoy profits above the competitive level. In the analysis presented thus far, tenderers' behavior was assumed to be non-cooperative. Thus, any kind of communication, sharing of information or coordination of acts among tenderers was not

allowed. Yet in practice, auctions are very vulnerable to collusive behavior on the part of bidders. Collusion among bidders is very tempting since cooperative behavior strictly dominates non-cooperative behavior; that is, the expected revenue for bidders is larger if they cooperate and engage in collusive behavior than the case of bidding in a non-cooperative way. Indeed, allegations of collusion in both private and public auctions are widespread, and evidence for such behavior is available in highway construction (Porter & Zona, 1993), real estate, works and utility procurement (McMillan, 1991), the milk industry (Pesendorfer, 2000), as well as many other auction types (Cassady, 1967).

One important weakness of collusive behavior in auctions, however, is that cartels are inherently unstable, since members to a cartel will usually find it beneficial to deviate from the agreement and to cheat on their associates. For that reason, additional criteria for a comparison among auction formats may be their ability to 'take advantage' of such weakness and to make collusion among tenderers unstable. Thus the next question may be which auction format can best prevent cartels from enforcing themselves.

Economic theory submits (Robinson, 1985) that cartels are generally stable under the English and second-price formats but not under the first-price auction. This is due to the way bidding cartels usually work. In order for a cartel to be successful, members must determine in advance who should be the bidder that will represent the cartel in the real bidding. Moreover, all remaining bidders must agree not to compete against this bidder and thereby allow him to win the bidding. Usually, the representative bidder should be the one with the highest evaluation of the contract, since he is the best one to 'compensate' all remaining bidders for his winning. In order to decide who should be the representative bidder, parties to a cartel may engage in a 'second-price pre-auction knockout' (PAKT), (Graham & Marshall, 1987; McAfee & McMillan, 1992), in which each member submits his own evaluation prior to the real auction and the winner is determined in a similar way as a normal second-price auction. The winner of the PAKT is then selected to submit his bid, whereas other members are not allowed to submit their bids at all or alternatively to submit only 'non-competitive' bids.

Under a second-price sealed-bid auction, the difference between the lowest bid and the second-lowest bid submitted is the profit of the cartel, and will be distributed equally to all the cartel members. Since none of

the bidders is able to submit a better price than the bidder with the highest evaluation, i.e., the one chosen by the PAKT, none of them has incentives to cheat because there is no possible gain by doing so. It follows that under the second-price sealed-bid auction, cartel arrangements are relatively stable.

For the same reasons mentioned above, bidders do not have incentives to cheat on the cartel in an English auction as well. This is again because the one who was chosen to represent the cartel has the highest evaluation, and therefore no one is able to compete with his potential best price. Moreover, since bids are submitted publicly, all members of the cartel are immediately aware of any defection of the original plan, and are able to 'punish' those who defected on next rounds.

It is only under the first-price sealed-bid format that the cartel is less stable. Recall that in a first-price sealed-bid auction, the winning bidder pays the sum of his bid. Therefore, a cartel representative in procurement bidding is required to submit a relatively higher bid in order to enable the cartel to enjoy substantive profits. Knowing that, other members of the cartel might be tempted to defect and submit only slightly lower bids than the one submitted by the cartel, and thereby enjoy abnormally high profits in case of a winning. Due to this incentives structure, collusion in a first-price auction is much less stable than in the case of a second-price or English auction, since it requires an external enforcement mechanism to deter members from cheating and enforce their cooperative behavior (McAfee & McMillan, 1992; Krishna, 2002). Paradoxically, rules aimed at curbing corruption and supporting transparency in public procurement, like those which require the publicity of the price and identity of the winning bidder,²⁵ may help a cartel to enforce collusion among its members by revealing the identity of the winner in case of a defection, and thereby allowing cartel members to 'punish' him.

There are two additional factors which make collusion more likely to happen. First, according to Stigler, collusion is more likely to occur in markets with fewer participants, since it is easier to communicate and enforce the agreement within a smaller group of members (Stigler, 1964). Second, the presence of the same group of bidders in similar and repeated biddings also increases the probability of collusion, since repeated interaction among bidders makes the profits of deviating in a single bidding much smaller given the expected profits from collusion in the subsequent periods (Gupta, 2001).

To summary, according to economic analysis, collusion is more likely to occur in a reverse English auction procedure than in a first-price auction. This fact should be considered carefully when conducting competitive bidding in industries with fewer numbers of potential bidders, or in cases of repeated bidding. In such cases, the advantages of using the first-price auction are apparent.

IS AUCTION THEORY APPLICABLE TO PUBLIC PROCUREMENT IN PRACTICE?

The economic analysis of auctions provides an important yet complicated method of design and evaluation of competitive bidding. For example, the theory submits that in some cases there are effects that work in opposite directions, such as risk aversion and dependent valuations. Thus, the determination of which effect is stronger can only be established if enough data is available. Moreover, in many cases the information which is required to decide what set of assumptions should be applied in specific situations is not always available. This is particularly true in identifying bidders' valuations distribution. Perhaps the greatest difficulty with the application of auction theory in practice is that it is doubtful whether the set of assumptions chosen to facilitate calculations really correspond to reality and whether the mathematical calculations made accordingly are capable of simulating people's behavior with a high degree of confidence. On top of that, some of the policies recommended by auction theory might be followed by high transaction costs, thus outweighing the benefits that are brought by them.

Nevertheless, by learning auction theory, the current procurement regime can be improved. First and foremost, by recognizing that auction design plays an important role in the outcome of the procurement and that 'one size does not fit all,' contracting entities are better able to utilize the advantages available by such a market mechanism. Perhaps the best evidence to this fact is the third-generation mobile-phone license auctions that were held in several European countries during the years 2000-2001. Even though the licenses in question were almost identical in all cases, the differences in auction design had a significant impact on revenues, which varied from 20 Euros per capita in Switzerland to over 650 Euros per capita in the UK (Klemperer, 2002).

Another example of the importance of auction theory in practice is provided by a comparison between the radio spectrum auctions held in

New Zealand and the U.S. The first time an auction was used to distribute spectrum rights was in 1990, when New Zealand used a second-price auction for that purpose. Due to flaws in the design of the auction, winners paid prices that were far below their bids. In one case, the highest bidder offered NZ\$7 million but ended up paying the second highest bid, which was NZ\$5000 only (McMillan, 1994). In 1994 (the same year in which John Nash was awarded the Nobel Prize for his game-theory analysis), the U.S. Federal Communication Commission (FCC) used an auction for the selling of the electromagnetic spectrum for personal communications services. In this case, both the FCC as well as the major telephone companies relied on the advice of auction theorists. The theorists recommended the form of auction to be used, the method, and the rules governing participation and bid submissions (McMillan, 1994). The form of auctioning finally chosen was an on-line simultaneous ascending auction in which multiple licenses are open for bidding at the same time and remain open until no one wants to continue bidding. Bidding further occurred in rounds, where bidders have the results of each round announced before the next round starts (McAfee & McMillan, 1996). This time the result of the auction was undoubtedly successful as revenues exceeded most optimal assessments and newspapers headlines announced that game theory is the new business tool for best practice.²⁷

Even if auction theory is not able to offer one decisive and complete model of auctioning, in most procurement procedures auction theory may be used to capture at least several parts of the matter and to explain people's behavior in various circumstances. Where auction analysis is able to offer clear results, legal theory is certainly able to benefit from using economics to examine the law. In cases where clear-cut results are not available, the intuition and experience gained by a myriad of theoretical and empirical works on auctions may help public officials to better predict the effects of the circumstances in which competitive bidding is conducted on the behavior of potential tenderers. Furthermore, by relying on auction theory, public officials are able to identify the tradeoffs involved in changing certain circumstances of the bidding environment and thereby improve current procurement techniques. The electronic reverse auction is one example of such improvements: there is already compelling evidence that, if used properly, reverse auctions have the potential to yield better economic results. The U.S. Army, Navy and the General Services Administration were able to significantly decrease

costs of contracting by using the reverse auction procedure. For example, it was reported that the Navy saved more than \$3.7 million on its first two online reverse auctions held in May 2000 (William, 2000), and the Defense Energy Support Center, which held its first reverse auction in August 2000, saved about \$425,000 off the cost of a month's worth of natural gas for Washington-area military installations (William, 2000). Turley (2002) provides more compelling evidence on the success of the reverse auction in reducing costs of contracting and pursuing better value for money in the U.S. army.

CONCLUSION

It is possible to draw few practical conclusions from the analysis above with respect to competitive bidding for public procurement. Above all, the fact that auction formats may be ranked according to their ability to save on taxpayers' money and to allocate contracts to the most competitive firms cannot be underestimated. In those cases in which the electronic auction procedure is clearly preferable to the traditional procedure from an economic point of view, and given the clear priority it enjoys with respect to transparency, it should be considered to give a statutory priority for using the electronic auction procedure in a similar way to the priority the open ("traditional") procedure has over the negotiated procedure.

According to economic theory, the electronic (English) auction is superior to the first-price auction in several aspects. First, regardless of the tendering circumstances and bidders' characteristics, the English auction is the only format in which tenderers' dominant strategy is always to be 'truth telling,' hence, to bid their own real evaluation. This in return may secure that contracts are assigned to the most competitive providers available and thereby guarantee a long-term growth of the market. Second, in most cases of procurement (i.e., when tenderers have affiliated valuations), the English auction is also better able to secure best value for money, which is an important commercial goal at the national level. Third, the fact that the English auction is conducted via electronic means reduces many administrative difficulties and costs associated with the traditional open procedure, such as costs of handling and evaluating bids, costs of communication, and even costs that potential bidders spend on industrial and business espionage before submitting bids. The fact that the English auction is better capable to mitigate the problem of the 'winner's curse' is also an additional advantage with comparison to the

first-price auction. Finally, the English auction is favored over the traditional procedure due to its increased transparency of the contract award process, which is an important factor in the implementation of EC as well as national procurement policies.

On the other hand, the application of the electronic auction procedure is limited by definition. This is because it is applicable only to contracts which entail elements that are quantifiable so that they can be expressed in figures or percentages. Tenders, in which non-quantifiable elements must be evaluated, cannot be subject to the electronic auction. Consequently, many contracts, such as those that have intellectual performance as their subject matter or design of works, are subject to the traditional tendering procedure only.²⁷ Moreover, the reverse auction is more susceptible to collusion in comparison to the first-price auction. This fact must be taken seriously, especially in projects which are characterized by a small number of bidders, or in repeated bidding in which the same group of bidders participate. Last, it is possible that the electronic auction is inferior to the first-price auction from a revenue point of view when bidders are risk-averse. However, the latter is not a clear-cut result, especially when bidders' valuations are dependent.

A recent and clear example of the willingness of the Commission to employ more economic procedures in the award of contracts is the adoption of the reverse electronic auction. The analysis provided in this paper implies that such measures have the capability to mitigate the conflict between the Commission and national policies in public procurement. This may be done by allowing national procuring entities to use more commercial techniques of competitive bidding, as long as they do not interfere with the main purpose of the European Directives, which is the opening up the market to supra-national competition. Moreover, by pursuing such aims, Member States are actually serving the ultimate goal of the EC Treaty, which is achieving better economic performance and prosperity in Europe.

NOTES

1. Other ways to meet their requirements is by setting up state-owned facilities and industry, or by confiscating means of production from the private sector (Arrowsmith, 1998).

2. The volume of total public procurement further varies by Member States from 11.9% in Italy to 21.5% in the Netherlands (European Union, 2004).
3. For instance, the 1987 Single European Act, which established a legislative program comprised of 282 directives designed to achieve the common market in many aspects and the Cecchini Paolo (1988) report which provided the economic justification for completing the internal market. By 1993, a series of directives had been adopted in the field of public procurement, regulating the way and defining the scope of purchases made by entities which procure works supplies and services.
4. The new legislation package is composed of Directive 2004/17/EC of the European Parliament and of the Council of 31 March 2004 coordinating the procurement procedures of entities operating in the water, energy, transport and postal services sectors; Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts.
5. For the interference of the EU strategy in national public procurement policies, see Arrowsmith (2002).
6. Monopsony differs from monopoly by the fact that, in the latter one, seller faces many buyers, whereas in the former one, buyer faces many sellers.
7. That is the free movement of goods, services, persons and capital. With respect to public procurement, the first two freedoms are of special importance. See in Articles 28 and 49 EC.
8. Article 12 of the EC Treaty
9. Article 43 of the EC Treaty
10. For non-discrimination as a general principle in EC law, see Case 1/72, *Frilli v. Belgium*, ECR 457 (1972).
11. Beginning with the first directive on public works contracts in 1971 through the adoption of the 1992 legislation and with the approval of the last legislative package in March 2004: Dir. 2004/17/EC of the European Parliament and of the Council of 31 March 2004 coordinating the procurement procedures of entities operating in the

water, energy, transport and postal services sectors (30.04.2004); Dir. 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts (30.04.2004).

12. The first doctoral degree awarded in 1956 for a dissertation on competitive bidding was given to Lawrence Friedman (1956). However, the development of auctions as a field of research is contributed to William Vickrey and his pioneering work from 1961 (Vickrey, 1961).
13. Also known as the “Vickrey auction,” after the name of the first economist who analyzed it
14. For empirical studies of auctions, see Hendricks and Paarsch (1995); Hendricks and Porter (1988); Laffont, (1997); Laffont and Vuong (1996).
15. To illustrate the meaning of “Independently distributed,” it is possible to think on the case where numbers ranging from one to fifty are printed randomly on notes and put in one box. The probability that someone will pick a note with a certain number depends on how many notes there are in the box and the number of notes printed with that particular number. Since the total numbers of notes, as well as the number of notes with the same number, have been determined randomly, a guess made by one person as to what number will be picked next is statistically independent from another person's guess. The assumption of Independent distribution in auctions reflects the situation that the object might have a range of values, and participants in the auction have different valuations that are statistically independent.
16. In Nash equilibrium, each player's strategy choice is a best response to the strategies that are actually played by his rivals. When tenderers correctly predict the bidding strategies of their competitors and choose their own bidding strategy in accordance, the collection of all strategies will result in Nash equilibrium of the bidding game. This is the case when neither tenderer can increase his expected payoff by deviating unilaterally from his equilibrium strategy. See Mas-Colell, Whinston and Green (1995, pp. 246-247).

17. A dominant strategy is defined as the optimal ‘move’ for a player, regardless of what all other players do.
18. The condition of course is that there are more than two tenderers, since the information is gathered from tenderers who drop out early. If there are only two tenderers, the winner will be declared immediately after one of them drops out, without giving the opportunity to gather information. Thus, in the case of two tenderers, the English and the second-price auctions are equivalent from expected revenues as well.
19. See Article 55 of directive 2004/18/EC and Article 57 of Dir. 2004/17/EC.
20. See joint cases C-285/99 and C-286/99 *Impresa Lombardini SpA* 27.11.2001 ECR (2001) I-9233
21. In general, a person who considers the utility of a certain given income to be higher than the expected utility of an uncertain prospect of equal expected monetary value is considered as being risk averse. See Cooter and Ulen (2004, pp. 50-53).
22. See the 32nd recital in the preamble of directive 2004/18/EC on the encouragement of the involvement of small and medium-sized undertakings in procurement contracts. In the U.S. the Federal Acquisition Regulation (FAR) deals specifically with small business programs under part 19. See FAR § 19.000.
23. For more on auction environments in which both risk aversion and affiliated values are present, see Page (1994).
24. This is because one of them considers his evaluation low in comparison to other evaluations in the same distribution function from which he drew his evaluation, whereas the other considers his evaluation high in comparison to other evaluations in his distribution function.
25. See Annex VII A of Dir 2004/18/EC on information which must be included in public contract notices.
26. See Article 14 in the preamble of Dir 2004/18/EC.
27. *The Wall Street Journal* (February 13, 1995, p. A19) remarked that “Game theory is hot;” the *Economist* (July 23, 1994, p. 70) remarked that “when governments auctioneers need worldly advice, where can

they turn? To mathematical economists, of course.” See further remarks in McAfee and McMillan (1996).

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