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Public Procurement and Reputation: An Agent-Based Model

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Public Procurement and Reputation: An Agent-Based Model

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Abstract

Based on the literature on public procurement regulation, we use an Agent-Based Model to assess the performance of different selection procedures. Specifically, we aim at investigating whether and how the inclusion of reputation of firms in the public procurement selection process affects the final cost of the contract. The model defines two types of actors: i) firms potentially competing to win the contract; ii) a contracting authority, aiming at minimizing procurement costs. These actors respond to environmental conditions affecting the actual costs of carrying on the project and unknown to firms at the time of bidding and to the contracting authority. The results from the model are generated through simulations by considering different configurations and varying some parameters of the model, such as the firms? skills, the level of opportunistic rebate, the relative weight of reputation and rebate. The main conclusion is that reputation matters and some policy implications are drawn.

JEL classification codes: H57; L14
Keywords: Public works; Procurement; Agent-based modelling.

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1 Introduction

The performance of public procurement is a widely debated issue worldwide at political as well as at economic level. The relevant share of public spending involved by public contracts (about 15% of GDP in developed countries) calls for obtaining 'value for money'.

The potential of procurement to improve overall public sector performance is also increasingly recognized and crucially depends on the set of rules governing public contracts. Even assuming that public decisions on resource allocation - e.g. what to procure and where – are efficient, still the final outcome mainly depends on the rules for the design of the procedure, the selection of the contractor, the contract award and implementation. The economic issues involved in procurement are mainly related to asymmetric information, both in the form of adverse selection (i.e. the problem of choosing the best private contractor) and of moral hazard (i.e. the problem of preventing opportunistic behaviour in the implementation of the contract). Procurement rules should be designed to address and overcome the above problems.

The economic problems related to public procurement regulation are widely addressed in the literature. Several papers investigate awarding procedures, with the aim of identifying the incentives for firms to obtain the best contractual performance (e.g., Bajari and Tadelis, 2006; Ganuza, 2007; Bajari *et al.*, 2009; Bajari and Lewis, 2011; Corts, 2012; Decarolis, 2014)

It is generally believed that public procurement asymmetric information problems can be overcome through procedures designed to ensure competition. Competition is considered as a tool to achieve efficiency and 'value for money' but also to keep contracting authorities accountable by limiting their discretion in selecting the contractor.

Indeed, the efficiency of open procedures should not be taken for granted for public works. In fact, in such a case, unlike supplies contracts, procurement does not refer to standardized products, which already exist in the market, but the execution of the contract implies a production process. Public works in most cases rely on long-term contracts, which are often incomplete (Bajari and Tadelis, 2006). The incompleteness of contracts may give room to opportunistic behaviour of the winning bidder, resulting in a pressure to revise the original contract, with a negative impact, usually on the time and the costs of realization of public works (Bajari *et al.*, 2007; Guccio *et al.*, 2009).

As a matter of fact, delays and cost overruns in the execution of public works contracts are a widespread phenomenon in most countries (OECD, 2013). Therefore, in the case of public works, the outcome of public action strongly depends on the implementation phase and the rules governing it play a crucial role.

Notwithstanding the importance of the execution stage, most attention is concentrated on the selection stage. At this stage, to overcome the effects of adverse selection, procurement systems usually rely on restrictions to entry, based on qualification schemes for firms. Qualification is claimed to have beneficial effects on the functioning of the competitive system under incomplete information about the firms' capacities (OECD, 2010), provided that the technical, economic and financial requirements which are imposed by the qualification scheme are adequate. Estache and Iimi (2012) stress the relevance of the qualification screening process for the success of any contract; Ancarani *et al.* (2016) investigate the relationship between the execution of public works contracts and firms' qualification in Italy, obtaining robust evidence that fully qualified firms are more efficient in the execution of public works contracts.

Qualification, however, is a static approach, which does not provide incentives to firms in the implementation of the contract. A further step could be to select suppliers taking into consideration their past performance on the basis of their track records. Indeed, this is the case in private procurement.

The relevance of this issue is also recognized in the literature. Several papers have focused on the role of firms' reputation as a mechanism interacting with other crucial features of the regulatory framework - e.g. competition, market entry, procurer's discretion - to select 'good' suppliers and to guarantee 'value for money'. Guccio *et al.* (2012) find that the opportunistic behaviour of the firm is a relevant determinant of performance in presence of competitive tendering and suggest enhancing the role of reputation in the awarding of the contract, to prevent underbidding and the consequent renegotiation of the contract; Spagnolo (2012) presents some novel evidence on the benefits of allowing buyers to use reputational indicators based on past performance and reports preliminary results from a laboratory experiment. Hence, reputational mechanisms can be designed to stimulate rather than hindering new entry; Dellarocas *et al.* (2006) investigate the potentialities of reputation systems through on-line feedback mechanisms, to prevent contractual opportunism; Doni (2006) provides a theoretical model to show that including contractors' reputation in the awarding procedures can provide incentives to firms and have positive effects on the quality of the services.

Our paper builds upon this literature focusing on how different procedures adopted to select the winning bidder affect the performance of public contracts. Specifically, we are interested in assessing the outcome from public tenders when, other factors being constant, firms' reputation in awarding public contracts is taken into account.

To tackle this issue, we use an Agent-Based Model (ABM) which, indeed, is not meant to replicate every detail of real-world cases. Rather, we pursue a general understanding, potentially applicable to many cases, differing for a large number of aspects, and analyze how the combination of several effects may interact to generate outcomes. Indeed, the results of simulations offer some insights to evaluate procurement regulation. To the best of our knowledge this type of modeling has not been applied to procurement so far.

The remaining of the paper is organized as follows. In section 2 we briefly introduce the main features of the use of ABM, focusing on the advantages and limitations for policy assessment. Section 3 describes the crucial characteristics of our model. Section 4 presents and discuss the results. Section 5 offer some concluding remarks.

2 Agent-based modeling as policy assessment tool

ABM consists essentially in writing a computer program providing a simplified representation of a real-world setting. Executing the program, the modeler is able to produce a sort of *virtual history* of the simulated system; the study of the simulation may provide insights in understanding specific dynamics in the real world, which is difficult, if not impossible, to observe.

The methodological use of ABM is still subject to a lively debate. In some cases, ABM is meant to replicate the observed behavior of real world systems (e.g., Dosi *et al.*, 2010). Thus, the main methodological issue concerns the validation of simulation outcomes in respect of available real-world evidence (Fagiolo *et al.*, 30).

Since the beginning, the use of simulation concerns models populated by heterogeneous bounded rational agents acting out of equilibrium conditions. Academic studies using computer simulations have, therefore, been adopted by scholars concerned with actual events occurring in organizations and markets (Simon, 1996; Cyert and March, 1963; Cohen *et al.*, 1972).

Today, the label ABM is utilized as reference to computer simulation models designed to include interacting agents collectively contributing to non-linear aggregate properties of the system, and are commonly implemented in several areas of social and economic research (Tesfatsion and Judd, 2006).

Simulation models can also be deployed to tackle purely theoretical problems for which real-world evidence is simply not existent. These applications are particularly relevant in the study of potential policies that have never been tested in reality. In these cases simulation models allow for the construction of fictitious systems whose (theoretical) properties can be studied on the basis of arbitrary assumptions applied to the known features of the concerned system (Faber *et al.*, 2010; Di Maio and Valente, 2013). Further, empirical validation is obviously impossible and therefore a different methodological protocol to assess the results is required.

To the best of our knowledge this type of modeling has not been applied to procurement so far. Our paper employs the methodological approach developed in Valente (2017) which focuses on the assessment of the internal mechanisms within a system generating observed results, to be compared with those driving real-world systems. Indeed, the results of simulations offer some insights to evaluate procurement regulation.

3 Model description

Our paper applies the methodological approach developed in Valente (2017). Formally, we define "a model" as a set of variables associated to "equations", implemented as chunks of computer code producing a numerical value at each time of their execution. The value for each variable will be affected by the values of other variables included in its equation, besides, possibly, constant parameters. A simulation run consists in the repeated computation of all the variables of the model in a sequence of time steps, where some of the variables' values from a time step are fed into the computation of the values of variables in the following time step. The model generates as a result time series of values for each variable; its statistical elaboration allows to interpret both the results and, most importantly, the logical connections linking the model configuration (functional form of the equations and initial values) to the results. The interpretation of these logical links allows to produce solid conclusions on the properties of the simulated system, whose translation to real world cases, though cannot be taken for granted, may provide useful insights.

Our ABM aims at investigating whether and how the inclusion of firms' reputation, as crucial feature in the public procurement selection process, may affect the final cost of the contract. The proposed model defines two types of actors: i) firms potentially competing to win the contract; ii) contracting authority, aiming at obtaining "value for money". These actors respond to environmental conditions determining the actual costs of carrying on the project and unknown to firms at the time of bidding and to the contracting authority. We are able to control any aspect of the model, so as to assess how firms' features, selection criteria adopted by the contracting authority, and environmental conditions concur to determine the outcome of the virtual contracts.

A simulation run consists in a sequence of steps, each of which represents a virtual round for a public contract. Our model assumes a large number of contracts offered to the same set of firms, so that, at the end of the simulation, we can collect the final values generated within each setting and assess the influence of specific conditions. During a single step of a simulation run, all firms submit a bid to win a contract. One of them is assigned the contract; the related work is executed at the cost specified in the bid increased, possibly, by unexpected cost overruns. In line with the above mentioned literature, in our model the costs overruns can be due to: i) unforeseen technical difficulties encountered by the contractor during the execution of the contract; ii) extra-costs charged by the contractor and opportunistically omitted from the bidding price in order to win the contract. The contracting authority is assumed to be not able to distinguish between the two motivations, but clearly wishes to punish opportunistic firms while clearing firms claiming legitimate extra-costs. The core result of this paper consists in showing that it is possible to identify virtuous firms (those charging only legitimate costs) from those adopting opportunistic behaviours, i.e. bidding a low price to win the contract and, eventually, claiming un-motivated extra-costs, by relying on the firms' reputation. We show that even under the rather extreme assumption that the awarding authority does not have the information or the technical skills to contest potentially illegitimate claims. In our model we use as a proxy for reputation an index based on the data of cost overruns claimed by winning firms at the end of their contract on top of the price stipulated on their bid, however they may be motivated. The model assumes that firms may advance overrun cost for reasons legitimate (truly unexpected events) or opportunistic (strategically planned at the time of bidding). The index, leveraging on the statistical differences between the two cases, allow the awarding authority to automatically identify the nature of the firms and reward the best firms, both technically, i.e. having the lowest production costs, and strategically.

The model includes several random events, simulating the variability of conditions faced by real-world cases. We can control the probability distributions of these random events, so that while cumulating the results over several time steps (representing several contracts), we can assess the average performance of the selecting criteria adopted by the contracting authority. Below we report the details of the model.

3.1 Bidding price

Each firm at each time t computes its bidding price as the final result of a process that takes into account the specific capacity of the firm and a random estimation of the unexpected difficulties that may be encountered during the execution of the work. For simplicity, we assume that there is no difference in the quality of the works performed by different firms and, therefore, for the contracting authority, the reserve price is the only relevant variable.

The first stage of the process consists in estimating the real cost that the firm expects to face in case it is awarded the contract. This cost is computed by the firm on the basis of the self-evaluation of its skills in performing the required works, and a random component capturing possible estimating errors. Formally:

$$C_i^{Est} = C \times (1 - S_i) \times [1 + N(0, \Delta)] \tag{1}$$

where C represents the reserve price published by the contracting authority, the maximum cost to perform the work, implicitly including a share of profits. S_i represents the "skill" of the firm expressed as a percentage, with values ranging from 0, for firms unable to reduce the cost below the reserve price, to 1, for firms capable to deliver the contract at no costs. The final level of estimated cost depends also on random events, represented in the model by a random variable[1] whose expected

[1]Programming languages have the possibility to generate so-called pseudo-random numbers, numerical values changing each time the command is executed and respecting the desired stochastic properties. In our case we use a normally distributed random value with mean null and variance

value is 0 and variance determined by a system-level parameter, Δ, set by the modeler but not known to either firms or the contracting authority. This final element represents the volatility in the bidding prices due to the different ability of the firms in estimating potential unexpected costs faced during the execution of the works.

Notice that within the levels of "skills" used to estimate the cost, we implicitly include also the desired level of profits the firm aims to gain from the contract. In fact, from the perspective of the contracting authority, there is no difference between a highly skilled firm, able to perform the desired work at low cost but chasing very high profit margins, and a less capable firm satisfied with lower profits.[2]

Once the firm has estimated the expected cost, it computes the rebate, which it is ready to offer, expressed as a discount with respect to the reserve price C.

$$R_i^{Est} = 1 - \frac{C_i^{Est}}{C} \tag{2}$$

The estimated rebate may be increased by an additional reduction that the firm plans to declare opportunistically in the official bid. This is done in order to increase the chances of winning the contract and to recoup the extra-costs incurred during the execution of the contract at the end of the contract by renegotiating it.

$$R_i = R_i^{Est} + R_i^{Opp} \tag{3}$$

The firm-specific parameter ${R_i}^{Opp}$ is assigned by the modeler and is unobservable to the contracting authority, which consequently cannot distinguish between *realistic* and *opportunistic* rebates. It represents the tendency of a firm to "game" the system relying on the impossibility of the contracting authority to distinguish between justified claims of the costs overrun, due to genuinely unexpected difficulties, and the opportunistic ones. It is worth mentioning that while our model is designed to assess the results depending on different degrees of opportunism among competing firms, it is not able to discuss the existence and the origins of such a behavior. For this purpose, we also assume that a firm adopts a fixed and constant level of opportunistic rebate. This assumption clearly simplifies the interpretation of the results, while in real world the tendency of firms to resort to such behavior may change through time. Nevertheless, as noted above, we aim at investigating the mechanisms linking certain conditions to specific results, and to this purpose what matters is the relative distribution of firms adopting opportunistic behaviors (that we control). The possible dynamics of opportunistic tendencies are outside the scope of the present work.

controlled by the parameter Δ.

[2]This holds if we do not take into account quality features among differently skilled firms.

The bidding price is computed discounting the rebate from the reserve price:

$$B_i = C \times (1 - R_i) \tag{4}$$

The bidding price is the relevant parameter for the contracting authority to select the firm winning the contract, according to the rule described below, together with another information concerning each firm, i.e. *reputation*. We consider the reputation of a firm as a measure of its reliability, that is, the correspondence between the cost agreed in the work contract (i.e. the bidding price) and the final cost claimed by the firm when the contract is executed and the work is completed. The final cost claimed by the firm can differ from the cost agreed in the contract (i.e. the bidding price) for two reasons: i) opportunistic behavior, represented by unjustified claims, which are planned at the time of bidding, causing under-bidding; ii) actual unforeseeable technical problems emerging in the contract execution, causing genuinely unplanned extra-cost. Formally, we express the final cost claimed by the firm executing the contract as:

$$C_i^{Final} = C \times (\overbrace{1 - R_i}^{\text{Bid}} + \overbrace{N(0, \Delta)}^{\text{Extracosts}} + \overbrace{R_i^{Opp}}^{\text{Opportunism}}) \tag{5}$$

As shown in equation (5) the final cost is composed by three parts: 1) the bidding price; 2) the genuinely unexpected extra-costs incurred during the execution of the work; and 3), the above mentioned opportunistic extra-costs.

While in real-world cases there is generally the possibility for the contracting authority to verify, at least partially, the plausibility of cost overruns claims (and, potentially, challenging them), we assume for simplicity the extreme condition, i.e. that the contracting authority is not able to distinguish planned opportunistic extra-costs from unexpected ones. Consequently, the only information available to infer the reliability of a firm is to compare the final cost applied by the contractor with the relevant bid price, regardless of the possible causes of divergence. We aim at investigating whether in such conditions there may be a strategy for the contracting authority to reduce the damage due to the opportunistic behaviors.

We assume that the contracting authority maintains a register in which it records the performance through time of the firms to which it assigns contracts. Within the register each firm is associated to an index of reliability, called *reputation*, which is updated any time the firm completes a contract. At each time step, say t, only the reputation index of the winning firm is modified according to the following equation:

$$T_{t,i} = T_{t-1,i} \times \gamma + (1 - \gamma) \times \frac{B_i}{C_i^{Final}} \tag{6}$$

Equation (6) deserves some comments. Only for firms winning and executing the contract the reputation index changes, depending on the ratio of their bidding price and the final costs (for other firms it is unchanged). Given the assumptions described above, the final cost can be equal or larger than the bidding price, so that the ratio has a maximum on 1. In general, the ratio is lower the larger the final cost in respect of the bidding price. The functional form describes a sort of weighted average between the old value of reputation and the current result, with γ representing the relative importance of the past with respect to the most recent information. When $\gamma = 0$ the reputation of a firm corresponds always to the ratio bid/final cost recorded the last time the firm won a contract. On the other extreme, when $\gamma = 1$, the reputation of a firm does never change, remaining constantly equal to its initially assigned value. For the general case of intermediate values for γ we can represent a smoothed dynamics where any contract won by a firm shifts the reputation at an intermediate level in between the past level and the newly recorded performance. The property of such a system is that in the long term, when the number of contracts won is sufficiently large, the reputation index approaches the expected ratio of the bid over the final cost. This value will be smaller, other things being equal, for the firms having a higher opportunistic behaviour.

The final equation of the model concerns the mechanism by which the contracting authority assigns the contract among the competing firms. The mechanism consists in evaluating all the firms bidding for the contract and choosing the one to award the contract. While in our model we consider exclusively the firms' bidding price and their reputation index, we adopt a modeling format implicitly representing the case where firms are assessed along a wider range of characteristics, potentially affecting both features of the firms or aspects of the proposed contract. For this reason we analyze a selection mechanism of the winner which includes a random factor, though the chances of winning are higher for firms enjoying the highest rebate and the best reputation. Formally, the firms are selected randomly according to probabilities proportional to the following index, computed for each firm at each time step:

$$I_i = \left(T^a_{i,t-1} \times R_i^{(1-a)} \right)^b \tag{7}$$

The indices for all the firms are turned into probability by standard normalization:

$$Prob(i) = \frac{I_i}{\sum_j I_j} \tag{8}$$

Summing up, at any time step each firm computes its rebate, then the awarding authority uses this information and the reputation index to define the probability associated to each firm, and then draws randomly one firm according to those probabilities.

The format of equation (7) (and consequently of the probabilities of winning the contract) allows to explore a variety of possible conditions. Parameter a expresses the relative importance of the reputation with respect to the rebate value, as a criterion to choose the winner and to award the contract. For example, setting a=0 we represent the contracting authority dismissing the reputation and considering only the rebate, and viceversa when a=1. For intermediate values of a we produce settings where the relative importance of the two bits of information are more or less relevant in assessing the tender's winner. Parameter b represents the intensity of competition, meaning that we can tune the model to provide more concentrated or distributed probabilities. To appreciate the effect produced by varying the value of b, consider a set of firms with varying levels of reputation and different rebates and a given level for a, and compute two sets of indices I using two different values for b. In both cases the relative ranking position of each firm will be identical in the two sets. However, the probabilities of the top ranking firms, those with the highest indices, will be much higher when using a higher value of b with respect to the probabilities computed with the lower value, which may be interpreted as a case with stronger competition restricting the actual chances of being selected only to a few, top performing firms. On the contrary, with a low level of b, the probabilities are more evenly spread across all firms, though the best firms still enjoy a comparatively higher chance of being selected. This second case represents a lower competitive pressure, since over repeated draws a larger number of firms will be selected.

4 Results

The results from the model[3] previously described have been produced by considering different configurations and varying some parameters, such as the firms' skills, the level of opportunistic rebate, the relative weight of reputation and rebate, etc. Comparing these results we will be able to highlight logical properties of the proposed model and shed light on the outcome that may be expected from different regulation alternatives and environmental conditions. It may be worth repeating that the simulations presented are not aimed at being realistic; indeed, the goal is to identify the mechanisms acting within the simulated virtual system, so as to derive useful insights to interpret real world evidence as well as policy implications.

We present four scenarios. Scenarios 1a, 1b and 1c provide preliminary evidence, based on extremely simplified configurations, mostly aimed at clarifying the single effects of the model's core dynamics; scenarios from 2 to 4 provide more complex results including the interplay of the different components of the model.

In all the scenarios presented below, we consider a simulation run made of a large number of steps (5,000); during each of them a contract is awarded to one among 1,000 firms. These large values, obviously exceeding any reasonably realistic case, are due to the necessity to smooth away the effects of randomness and to increase the reliability of results.

[3]The model is implemented with the *Laboratory for Simulation Development - LSD* (Valente, 2008). Source code and configurations are available upon request.

4.1 Scenario 1a: Introduction

We first consider the outcome produced when the reputation is completely ignored. To this end we test the effects generated when the contracting authority evaluates firms only on the basis of their bid, rewarding with a higher probability of winning the contract the firms presenting the highest rebate. We also assume that firms do not apply any opportunistic rebate and the probability of unexpected problems is set to null, so that the final cost depends only on the skills of the firm (i.e., its actual cost, including the implicit profit).

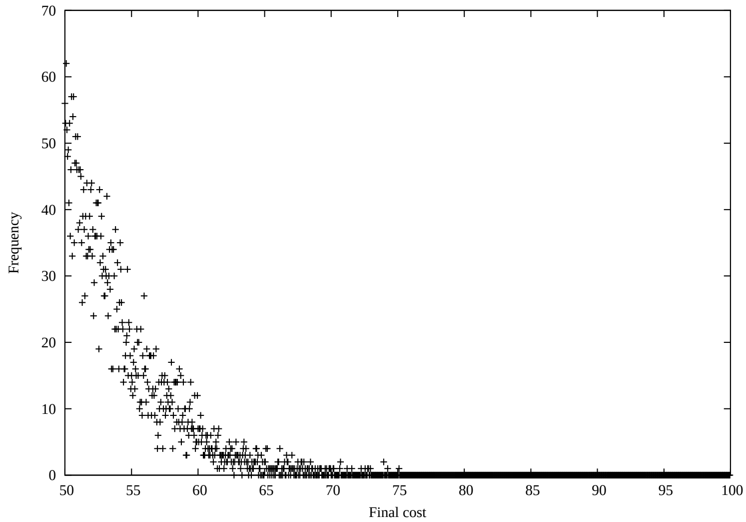

Figure 1: Frequency of contracts awarded distributed according to their final cost.

Figure 1 shows the data obtained at the end of a simulation run. It reports on the horizontal axis the final cost charged by the winning firm at each time step and, on the vertical axis, the frequency with which that level of cost occurred. The configuration includes firms with different levels of skills, and, therefore, final cost. The result shows clearly that firms with the highest cost (lowest skills) are never selected (the reported frequency is equal to zero), suggesting that they never manage to win a contract during the whole simulation run. Firms with mid- to low-cost (mid- to high skills) correspond to increasing frequencies; maximum frequencies are reached for those with the lowest cost. The distribution is noisy due to the random component in the selection mechanism. As noted above, this mechanism generates higher probabilities that the contract is awarded to firms with the highest rebate bids, but any firm enjoys at least an infinitesimal, non-zero probability of being chosen.

4.2 Scenario 1b: Reputation and skills

Figure 2 reports the values of the reputation index earned by the firms ranked according to their skills. This index is updated only for the firms, which have been awarded a contract at each time step. Therefore, the more contracts a firm wins the more frequently its index is updated. Under the conditions adopted for this scenario, the index can only grow from its initial low level of 0.5 because firms never indulge in opportunistic behavior and there is no randomness in the costs. Consequently, a) the reputation index can only increase, approaching the long-term maximum level of 1, and b) at any given time, we observe that the firms with larger number of awarded contracts also show the best reputation indexes.

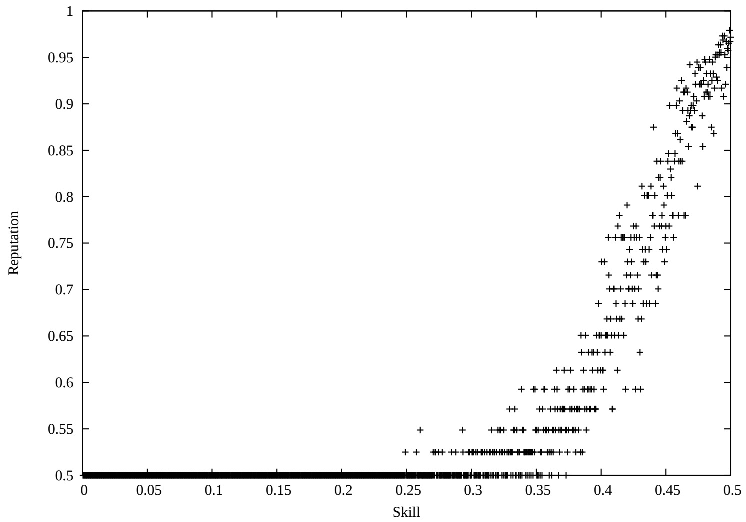

Figure 2: Reputation index for firms distributed according to their skills.

4.3 Scenario 1c: Selection mechanism and competitiveness

As last evidence, we consider the effect of the selection mechanism. The competitiveness of such a selection is controlled by the parameter *b,* whose higher values favour the selection of firms with the highest indicators. In this simplified configuration we use as introduction to the model, the indicators coincide with the skill of the firms. Therefore, the highest the indicator, the lowest the final cost charged by the firm if it was awarded the contract. Selecting firms with the best indicators thus favors the selection with the highest skills, and, on average, guarantees lower costs.

Figure 3 reports the data from ten distinct simulations each using the same set of firms and ten different values for the selection pressure. The graph reports on

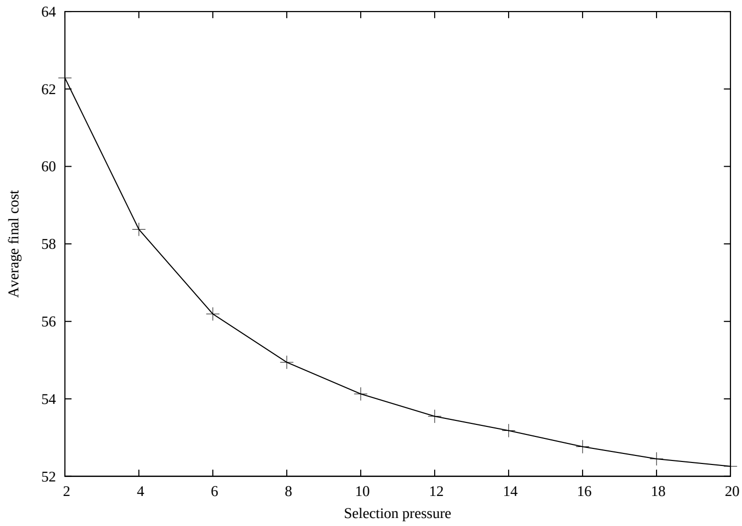

Figure 3: Average final cost of awarded contracts and selection pressure. Comparison of the average final cost over all contracts awarded during a simulation run using 10 distinct simulations based on different levels of selection pressure (parameter b).

the horizontal axis the value of the parameter controlling the selection pressure and on the vertical axis the average cost paid by the awarding authority. Configurations with lower selection pressure spread their choice more widely, giving higher chances of being selected to firms with less than optimal skills. On the contrary, increasing the selection pressure, the range of firms selected is narrowly restricted to those with the highest skills, resulting in lower costs.

4.4 Scenario 2: Effects of opportunism

The effectiveness of the selection pressure in identifying the best firms and allowing the contracting authority to minimize the final cost is heavily reduced, and potentially disappears, when the firms leverage on the impossibility to distinguish genuinely unexpected extra-costs or opportunistic behaviours.

To support this result we consider the simulation used in the previous exercise and modify the parameters, defining the level of the opportunistic rebate, previously set to 0 for all firms. In this second exercise firms adopt different levels of opportunistic rebate, inversely proportional to their skills. In other terms, firms with low skills compete with a low bid price but, if they win the contract, they will charge a higher price, pretending opportunistic extra-costs, so that the work becomes more expensive than expected.

Figure 4 shows the average skill level of the winning firm on the vertical axis for different levels of the selection pressure. The continuous line reports the results from exercise 1, where firms do not engage in opportunistic activities, while the dashed

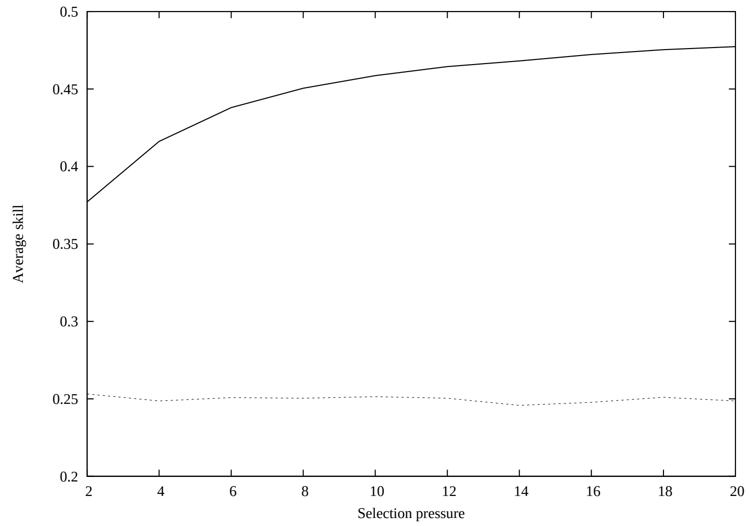

Figure 4: Average skill of the winning firms for different levels of selection pressure. Thick line represents data from experiment 1, where firms do not use opportunistic rebates. Dashed line refers to experiment 2, where firms apply a level of opportunistic rebate inversely proportional to their skills.

line considers the results from this second exercise with opportunistic firms. It is evident that the selectivity of the contracting authority has no effect in the second case, since the skills of the winning firms remain constantly low independently from the concentration of probabilities. The reason for this result is that all firms submit low bids, and the contracting authority is not able to distinguish those doing so because of their high skills from those planning to claim opportunistic extra-costs.

4.5 Scenario 3: Reputation vs opportunism

In this third scenario we show how considering the reputation gained by a firm helps in contrasting opportunism. Similarly, to the previous exercise, we analyze a set of firms with value of opportunistic rebate inversely proportional to their skills. We consider two distinct simulation runs for the same set of firms. In the first run, the contracting authority takes into account only the level of the rebate to select the winner of the tender (value of $a = 0$), while in the second it also cares about the role of reputation ($a > 0$).

Figure 5 displays the records for the individual firms at the end of the simulation run. On the horizontal axis the graph reports the level of the skill of the firm, while on the vertical axis it shows the number of contract won. The cross symbols refer to the configuration where the contracting authority ignores the reputation of the firms. In this case the firms with the largest levels of opportunistic rebate have larger chances of being selected. Since the opportunistic rebate is negatively correlated

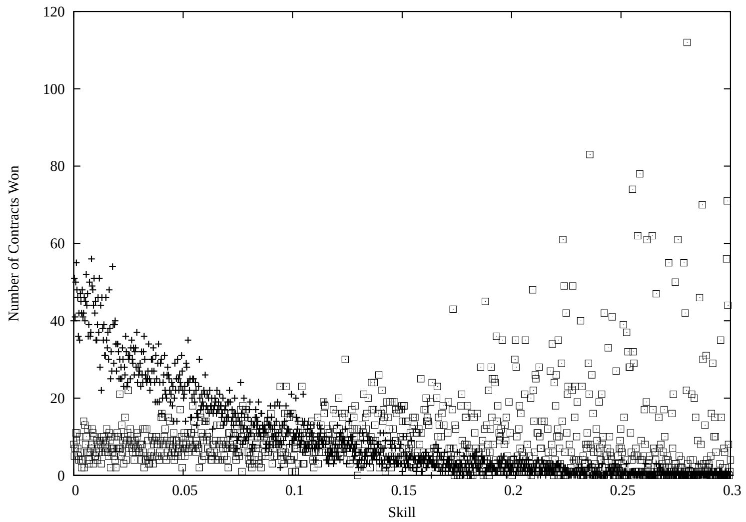

Figure 5: Number of contracts won for firms with opportunistic rebates inversely proportional to skills. The graph reports the data from two simulations run on the same set of firms. The cross symbols refer to the configuration ignoring the level of reputation, while the squared symbols refer to the simulation using reputation as criterion to assign contracts.

with the skills, this setting effectively rewards worse firms with higher number of contracts. The squared symbols refer to the configuration where the contracting authority also considers the level of reputation that increases more markedly for the firms with the lowest levels of opportunistic rebate. This configuration rewards the firms with the higher skills, since those with the higher opportunistic rebate see their reputation falling comparatively to those with higher skills.

4.6 Scenario 4: Reputation and randomness

In this final scenario we analyze the results produced when the final cost is affected both by skills and opportunism and also by genuine extra-costs due to unexpected problems occurred during the execution of the contract. Consequently, the contractual cost and the final cost may differ because of two possible reasons: opportunism or unforeseen contingencies. Having assumed the extreme scenario, in which the contracting authority has no chance to distinguish the two cases, it may be reasonable to expect that the reputation, computed in terms of cost overruns, fails to identify firms with higher opportunistic tendencies. As before, for benchmarking we also report the same data from a configuration without the use of reputation.

Figure 6 shows that the reputation continues to correctly discriminate against firms claiming unjustifiable higher costs. The graph reports the same data shown in figure 5, that is the number of contracts won by firms ranked according to their skills. Reminding that in this setting the level of opportunistic behavior is inversely

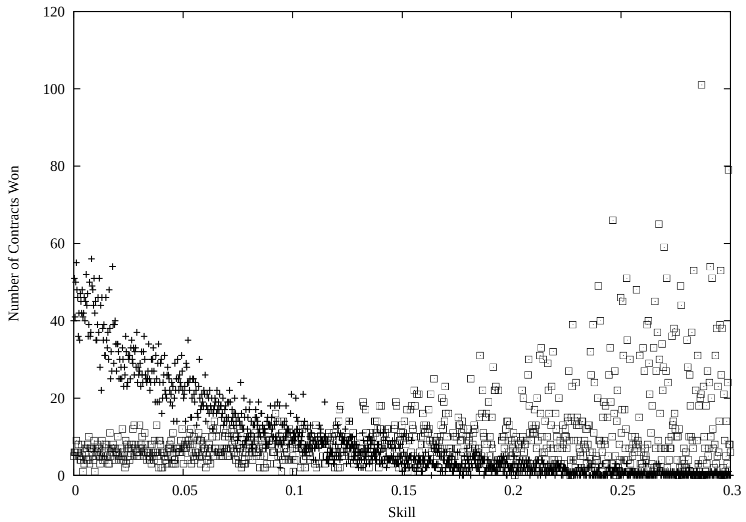

Figure 6: Number of contracts won for firms with opportunistic rebates inversely proportional to skills, in presence of randomness. Same data as in figure 5 but the simulations include also a random component affecting the final cost, so that a difference between contractual cost and final cost may depend from opportunism or genuinely un-expected extra costs.

proportional to the skills, the graph can be interpreted as showing the firms inversely ranked according to their opportunism level. The results are fundamentally identical to those generated without the possibility of extra-costs, proving that the presence of randomness does not modify the effectiveness of the reputation index. The only minor difference is the wider distribution of contracts among the highly skilled firms, suggesting a weakening impact of the reputational effect in promoting less opportunistic firms. However, these results maintain the rather extreme assumption that the awarding authority is unable to distinguish between legitimate cost overruns, due to unforeseen technical difficulties, from opportunistic extra-costs planned at the time of bidding. If the contracting authority had the possibility to investigate claims of extra-costs so as to expose even a small percentage of the opportunistic behavior, the effectiveness of the reputational effect would be strengthened.

The reason for the substantial robustness of the reputation in identifying the firms with the least opportunistic level (and higher skill) relies on the merely statistical effect of the randomness of difficulties. Both honest and opportunistic firms have the same chance of facing unexpected difficulties and, consequently, of reporting a different final cost at completion. However, opportunistic firms will present a wider difference on average. This difference, cumulated over several contracts, cause the reputation index to diverge, confirming its effectiveness. To support this claim we report in figure 7 the level of the reputation index for the same firms as in figure 6. It is worth noting that the simulation, where the contracting authority adopts the reputation as criterion to assign the contract, enhances sensibly the reputation of the

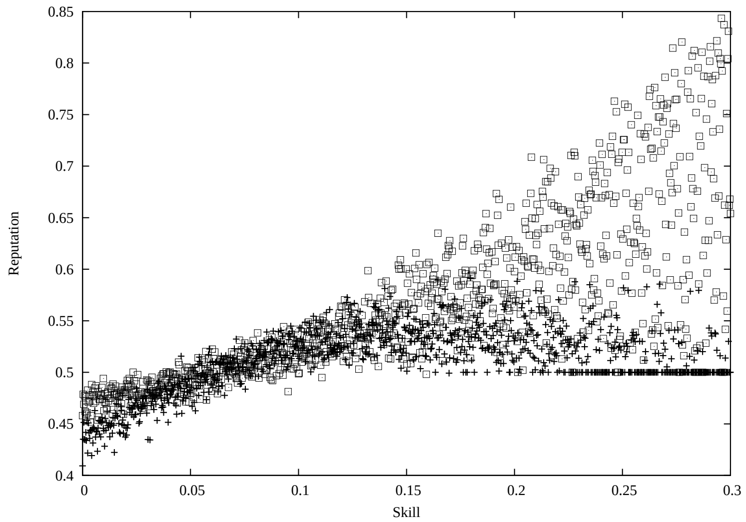

Figure 7: Awarded contracts and reputation (for different values of a) Same simulation as in figure 6. The graph reports the reputation levels of firms in respect of the skills. Square symbols refer to the configuration considering the reputation level to assign the probabilities of firms to be awarded the contract ($a > 0$), while the crosses report data from the simulation ignoring reputation.

least opportunistic firms in comparison to the case where the reputation is ignored. Obviously the reputation cannot reach the maximum level of 1 since, even if they are perfectly honest, firms still face un-expected extra-costs. However, opportunistic firms have lower scores and, therefore, can be easily identified.

5 Concluding remarks

In this paper, we used ABM as a tool to offer some insights on public works procurement regulation. The main results stemming from our analysis confirm the conclusions reached in the theoretical and empirical literature about the relevance of reputation as a tool to prevent opportunism in competitive procurement, to favour the assignment of a contract to the most skilled firm and to reduce the risk of cost overruns. By suggesting to include reputation as a selection criterion when deciding the assignment of a contract, our analysis contribute to the current debate on public procurement in the European Union, which is evolving towards considering reputation as a possible selection criterion. This issue is particularly relevant in Italy where the latest version of the Legislative Decree n.50/2016 (Procurement Code – *Codice dei contratti pubblici*) as modified by the law n. 96/2017 has introduced a reputational mechanism, i.e. a 'firms rating' mechanism, based on the potential contractor's past performances and aimed to be used both as a selection criterion of the contractors and a contract award criterion. The specific guidelines to regulate this new tool and to operate it by the National Anti Corruption Authority (ANAC) are still underway and no evaluation is possible at the moment. However the general principles provided by the law seem to be a weak answer to a crucial issue affecting the performance of public contracts. Indeed the mechanism is voluntary, rather than being a compulsory requirement to be evaluated by contracting authorities and this may effectively weakens the role of reputation in awarding the contract.

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