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An Empirical Analysis of The Main Drivers Affecting The Buyer Surplus in E-Auctions*

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We empirically examine the impacts of the product category, the auction format, the 2008 global financial crisis, the group purchasing, the contract type, the platform ownership, and the number of participating suppliers on the buyer surplus obtained from e-auctions. To this end, we collect a unique dataset from a purchasing organization that offers e-auction solutions to its corporate customers. By using a standard Tobit model, we show that the product categories, the auction type, and the number of participating suppliers have significant effects on the decrease in the procurement prices with respect to the minimum of the initial submitted bids. It is observed that the 2008 global financial crisis led to an increase in the buyer surplus. We classify the product categories into three groups based on their impacts on the average of the decrease in the procurement prices. We show that the average decrease in procurement prices is higher for the group purchasing option than for the individual buying option. It is concluded that the types of contract between buyers and auctioneer and the platform ownership have no statistically significant effects on the average decrease in procurement prices.

Key words: Procurement; Supply Chain Management; Group Buying; Reverse Auctions; Empirical Study; Statistical Analysis

1. Introduction

Procurement is one of the important business functions to ensure identification, sourcing, access, and management of the external resources that a firm requires for fulfilling its long and short term objectives. The procurement function is responsible for a number of initiatives from spending the firm's funds in sourcing goods and services to establishing and managing relationships with qualified suppliers. Ultimately, procurement has a significant effect on the firm's performance, not only in terms of cost but also in terms of quality, innovation, responsiveness, and revenue generation (Nair et al. 2015).

With the recognition of importance of the procurement in overall corporate performance, the majority of firms have started paying close attention to their procurement functions (Lawson et al.

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2009). As a result of these efforts, online procurement tools that the firms employ to strengthen the management of their supplier networks and the procurement processes have emerged in practice. Among these tools, electronic reverse auction, which is also known as procurement auction, e-procurement, business-to-business auction, has become a commonly used online procurement tool. In its basic form, an electronic reverse auction is an online, real-time dynamic auction between a buyer and a group of pre-qualified suppliers who compete against each other to win the business to supply goods or services that have clearly defined specifications for design, quantity, quality, delivery, and related terms and conditions (Beall et al. 2003).

The term *reverse* emphasizes the fact that buyers and sellers roles switch from that of a traditional auction. In the traditional auctions, also referred to as forward auctions, a seller offers a product that is demanded by several buyers who compete and bid up the price (Manoochehri and Lindsy 2008). At the end of the auction, the bidder who submits the highest bid is awarded the product. However, in a reverse auction, the buyer takes on the role of the seller and controls the auction process. The buyer announces its intent to purchase a specific quantity of a product or service. Suppliers of these items or of services compete with each other and lower their price to win the auction. As a result, the price of the object being auctioned decreases in the reverse auction, rather than increases as it would in the forward auction. Reverse auctions can be conducted in various formats, but the most popular ones are *English*, *Dutch*, *first-price*, and *second-price* auctions. Within the reverse auction context, the *English* auction is an iterative auction where the bidders submit subsequently decreasing bids. This iterative process continues until a price is reached where there is just a single bidder who is willing to supply the auctioning item. The *Dutch* auction is the reverse of the English auction where the price is monotonically increased by the buyer until there is a bidder who is willing to supply the auctioning item at the currently announced price (Chandrashekar et al. 2007). In the *first-price* auction, each bidder has the opportunity to submit a single bid by a particular deadline. Once the deadline expires the bids are examined and the lowest bidder supplies the good or service at the price she offered. In the *second-price* auction, the bidding rules are similar the ones employed in the *first-price* auction. However, when the *second-price* auction is employed the winning bidder does not charge the amount of her own bid, but the amount of the second-lowest bid.

In practice, most of the buyers prefer working with a specialized third-party service provider which is also referred as the market maker to conduct the reverse auctions, rather than building and employing their private infrastructures. Basically, the market maker is an intermediary firm, independent of the buyer and sellers that provides the facilities, processes, know-how and infrastructure to create an electronic market for conducting competitive bidding (Hsiao and Teo 2005). Their business models mostly depend on a fee that may be fixed, or proportional, or both to the value of the auctioned products and/or services (Mabert and Skeels 2002). For instance, Ariba, one of the

leading market makers, charges an extra fee that is 1%-3% of the transaction value on top of a participation fee. Covisint, another well-known market maker, only uses a fixed subscription fee to charge its corporate customers. In practice, the market makers not only offer the infrastructure and know-how that facilitates to conduct the reverse auctions, but also provide a practical framework to benefit from cooperation in purchasing. For this purpose, they operate group purchasing programs in which the buyers across different sectors can participate in for procuring common products through the online reverse auctions (Karabağ and Tan 2017). Within this context, the market maker acts as an intermediary firm that is authorized to conduct the auction on behalf of a group of buyers. In this case, the main function of the market maker is to get more price discount for the buyers by using their joint buying power with its own e-auction platform. In the literature, this mechanism is also referred to as joint procurement, purchasing consortium, and cooperative purchasing (Nollet and Beaulieu 2005). For a more detailed discussion on the group purchasing programs, we refer the reader to the works of Chen et al. (2009), Hu et al. (2012), and Karabağ and Tan (2017).

The choice of using, or not, the reverse auction is a typical tactical decision within the context of strategic sourcing (Standing 2009). Essentially, for the buyers, the reverse auction is a supportive procurement tool to response the strategic initiatives such as cost savings, demonstrate the transparency of purchasing decisions, reduce the cycle times of the procurement projects, access to a larger supplier base, and increase process efficiencies (Tai et al. 2010, Schoenherr and Mabert 2011). With the high level of competition in the bidding process and the visibility of competing bids, the supplier bids would be more fierce and hence the buyer would obtain lower purchase prices. Requests for information and bidding processes are prepared and completed electronically, instead of paper-based processes which are rather time-consuming. Hence, the cycle time and the administrative costs associated with the purchasing processes reduce whereas the efficiency of the sourcing process increases. The reverse auctions have the ability to bring buyers and sellers from all over the world together in an open environment as they are conducted through the internet. As a result, the true value of the auctioning item is clearly observed. The ease of access to the procurement event conducted with online reverse auction would also lead to a broader supplier base for the buyers. From the suppliers' perspective, most important motivations that drive the decision to participate in are the chances of reaching new buyers and having an outlet to sell the excess capacity (Karabağ and Tan 2017). The reverse auctions also help the suppliers to gain valuable information about the existing market, providing a better understanding of competitors' cost structures. Another important motivation for the sellers to engage in the auctions is a possible improvement in the negotiation time. The fact that less time is required for e-auctions compared to traditional competitive bidding reduces the supplier's reliance on forecasting for planning purposes,

as well as the administrative costs (Hartley et al. 2004). Detailed reviews regarding the motivations in which the e-auction implementations provide for the buyers and suppliers are found in the works of Elmaghraby (2007), Rothkopf and Whinston (2007), and Gupta et al. (2009).

The cost-saving is the key driver that incentives the buyers to adopt the reverse auctions into their procurement process. The reverse auctions have been shown to achieve a saving up to 40% on purchases of industrial goods and services (Jap 2002). Based on the case study of five larger firms in diverse industries, Hur et al. (2006) revealed that the use of reverse auctions led to initial price reductions of 13% to 20%. Additionally, Emiliani and Stec (2004) showed that by using the reverse auctions, a buyer in the aerospace industry was able to achieve a saving between 20% to 30% on purchases of indirect goods and a saving between 0.5% and 2% on purchases of direct materials. In practice, the cost-saving achieved with the use of e-auction implementations is typically measured by the difference between the historic price and the lowest bid. The *historic* price, also referred to as the *current* price, can be considered as the most recent price in which the buyer paid for the product before using the auction or as the minimum price in which the buyer received in the RFQ process that is conducted just before the auction (Amelinckx et al. 2008). In addition, the *lowest* bid refers to the final bid achieved at the end of the auction. With this definition, the cost saving basically measures the difference between the price a buyer is willing to pay for goods/services and the price a buyer actually pays. So, it is referred as the buyer surplus (Mithas and Jones 2007).

With growing attention on the reverse auctions due to its economic significance, the number of studies that focused on factors driving the buyer surplus has been considerably increased in the literature. Despite this fact, there are still a number of factors whose effects on the buyer surplus cannot be examined due to limitations on the datasets in the existing studies. In this study, we attempt to fill this gap in the literature by examining how the buyer surplus obtained through the reverse auctions is affected by the product category, the auction format, the 2008 global financial crisis, and the number of participating suppliers. Additionally, we attempt to address the impacts of the operational factors such as the contract type, group purchasing, and platform ownership on the purchasing prices. In this context, we collect a unique dataset from a third-party e-auction platform provider and conduct an empirical analysis.

The remainder of this paper is organized as follows. In Section 2 we give a detailed review of the literature on the analysis of the factors that affect the buyer surplus obtained in the reverse auctions. In Section 3, we provide a detailed discussion regarding the contextualization of the research questions with the existing studies. Section 4 develops the hypotheses for the empirical analysis. Section 5 gives insights into the profile of the company that we collected the dataset for this study and describes the characteristics of our dataset with a set of descriptive statistics. In Section 6, we introduce the methodologies used in the empirical analyses and discuss the reasons

why we choose them for the analyses. We present the results of the empirical analyses in Section 7 and discuss the main findings derived from the analyses in Section 8. In Section 9, we give the conclusions and limitations regarding this study.

2. Literature Review

In the literature, there are a limited number of empirical studies devoted to determining what factors could affect the buyer surplus. The datasets that analyzed in these studies typically include the transaction details of the e-auctions conducted either in the private or public sector. Based on this particular specification, we categorize the existing studies into two groups: (1) the studies that deal with the dataset from the private sector and (2) the studies that deal with the dataset from the public sector. We also cover the studies using the laboratory experiment datasets and surveys to examine the factors that drive the buyer surplus. In this context, in the following paragraphs, we only discuss the ones most related to our work. The studies that examine the e-auction implementations from the supplier's and third-party's perspectives are not included in the review as the corresponding literature stream is beyond the scope of this study.

2.1. E-auction studies with the private sector datasets

In recent years, there has been an increasing reliance on e-auctions for buying activities conducted in the private sector. E-auctions are being used for everything from purchasing agricultural commodities to acquiring high-tech manufacturing systems. Although there are numerous e-auction implementations in the private sector, the datasets regarding these auctions are typically not publicly available. As a result of this fact, the number of studies that deal with the datasets from the private sector is scarce in the literature. The need to develop theories and practices concerning the adoption, implementation, and utilization of e-auctions in the private sector has also been highlighted in several studies (Standing et al. 2010, Schoenherr et al. 2012, Pham et al. 2015).

Bapna et al. (2003) provide both analytical and empirical evidence regarding the importance of bid increment and lot size in the revenue generation. Koppius et al. (2004) investigate the effect of online product representation on the auction price by analyzing a dataset on flower auctions. The authors show that the deficient informational quality of the on-screen flower pictures in comparison to the real flowers leads to a decrease in the final price. Millet et al. (2004) study a dataset collected from a multinational firm and find that different auction types lead to different participation dynamics. They also find that the highest price reduction results are obtained by inviting at least five or six, up to a maximum of 13. Kauffman and Wood (2006) explore the factors that can be manipulated by the auctioneer to increase the bidder's utility, using the data gathered from eBay. The authors conclude that scheduling an e-auction in the weekend and the existence of a picture increase the price a bidder is willing to pay. By utilizing a dataset on the procurement auctions

of a firm in the automotive sector, Mithas and Jones (2007) study the effects of certain auction parameters on the buyer surplus. They claim that bidding competition and information asymmetry affect the buyer surplus whereas bid decrement and auction duration have no effects on the surplus. Park et al. (2012) study a dataset collected from an outsourcing company in Korea. The authors find that as the purchasing amount and number of bidders increases the winning bid price in the auction decreases. In the work of Tunca et al. (2014), the impacts of incumbency and supplier service quality on the buyer surplus are examined by using a dataset including the transaction details of the open-ended scoring auctions. They demonstrate that the open-ended award structure can improve the buyer surplus when the buyer's preference for non-price attributes is strong and the cost differences among the suppliers are low. By using a dataset collected from a third-party auction platform provider, Stoll and Zöttl (2014) establish a framework for the auctions where both price and non-price characteristics of the auctioning items matter for determining the winner. They find that concealing non-price information in the auctions leads to an increase in the buyer surplus up to 15% when the non-price characteristics of an auctioning item are of high importance for the buyers.

2.2. E-auction studies with the public sector datasets

A number of governments have initiated e-auction implementations to increase the transparency in their administrative works and to achieve better economic outcomes. As a result of this effort, a growing body of literature deals with the adoption of e-auction implementations in the public procurement and examines its effects on the auction prices. In this context, Onur et al. (2012) examine the effectiveness of the auctions that are organized by the public procurement authority in Turkey. They conclude that allowing foreign participants to participate in the auction and the threshold value for conducting an auction have notable effects on the number of bidders and the auction price. Based on the auction data from Slovak municipalities, Pavel et al. (2013) investigate the factors that may affect the auction prices and the efficiency of e-auctions. Their work shows that each additional bid submitted in the auction leads to a decrease in the auction price. Raventós and Zolezzi (2015) explore the impact of electronic auctions on the price paid by the public sector for pharmaceuticals and medical devices in Chile. They found that the price of drugs and medical devices falls with an increase in the number of bidders and/or the amount of auctioned items. Gurakar and Taş (2015) find that after e-auction adoption in Turkey, the number of firms submitting bids in the procurement auctions significantly decreases whereas the procurement costs rise. Based on these results, they conclude that e-auction adoption has adverse effects on the efficiency of government procurement auctions. The effects of subcontracting options on the auction prices are examined by Moretti and Valbonesi (2015). The authors observe that the bidders in a position to choose whether or not to subcontract mostly submit lower prices than the partially qualified firms which are mandated to engage in the subcontracting.

Study	Studied Factors											Data Specifications				
	Number of Bidders	Number of Bids	Amount of Item	Auction Duration	Reservation Price	Value of Information	Non-price Attributes	Supplier Incumbency	Product Category	Auction Format	Financial Crisis	**Origin of The Data**	**Auctioning Item(s)**	**Time Frame**	**Buyer Type**	**Auction Type**
Bapna et al. (2003)			✓		✓							E-auction Provider	Not Given	Not Given	1	1
Koppius et al. (2004)			✓			✓	✓					Auction House	Flowers	1995-1997	1	2
Kauffman and Wood (2006)					✓	✓		✓				E-bay	U.S. Rare Coins	1999-2001	1	1
Pearcy and Giunipero (2006)			✓									Survey	-	-	-	-
Engelbrecht et al. (2007)							✓					Laboratory Experiment	-	-	-	-
Mithas and Jones (2007)	✓	✓		✓	✓	✓		✓				U.S. Auto Industry	Manufacturing Parts	2001-2003	1	1
Park et al. (2012)	✓		✓									E-auction Provider	Manufacturing and Maintenance Parts	2001-2007	1	1
Onur et al. (2012)							✓	✓				P.P.A. in Turkey	Construction, Service and Goods	2004-2006	1	1
Elmaghraby et al. (2012)						✓						Laboratory Experiment	-	-	-	-
Haruvy and Katok (2013)								✓				Laboratory Experiment	-	-	-	-
Pavel et al. (2013)		✓			✓							P.P.A. in Slovenia	Construction and IT	2007-2009	1	2
Stoll and Zöttl (2014)						✓	✓					E-auction Provider	Service	2007-2008	1	2
Tunca et al. (2014)						✓	✓	✓				General Electric	Legal Services Contracts	2003	1	2
Gurakar and Taş (2015)	✓											P.P.A. in Turkey	Construction, Service and Goods	2004-2012	1	1
Moretti and Valbonesi (2015)							✓					P.P.A. in Italy	Construction	2000-2008	1	1
Raventós and Zolezzi (2015)	✓	✓	✓									P.P.A. in Chile	Pharmaceuticals and Medical Devices	2001-2006	1	1
Setia and Speier-Pero (2015)						✓						Laboratory Experiment	-	-	-	-
This Work	✓								✓	✓	✓	**E-auction Provider**	**14 Product Categories**	**2006-2016**	**2**	**3**

Note: P.P.A. stands for Public Procurement Authority.

Table 1 Summary table for the studies covered in literature review

2.3. E-auction studies with the laboratory experiment datasets and surveys

In the literature, there exist a number of studies investigating the factors that drive the buyer surplus by employing laboratory experiments or surveys. Based on a survey of 142 purchasing professionals employed in diverse industries in the U.S., Pearcy and Giunipero (2006) reveal that an increase in the amount of the auctioning item leads to a decrease in the unit purchasing price. Engelbrecht et al. (2007) compare the buyer-determined auction mechanisms where the buyer is free to select the bid that maximizes her surplus and the price-based auction mechanisms where the buyer commits to awarding the contract to the low price bidder. The comparison result emphasizes that the buyer-determined auction mechanisms increase the buyer surplus only as long as enough suppliers participated in the auction. With a laboratory experiment, Elmaghraby et al. (2012) explore how giving information to the suppliers about the bids that are submitted throughout the duration of the auction affect the buyer surplus. They find that giving the rank information to the bidders yields a higher decrease in the procurement prices, compared to giving the full information to the bidders. Setia and Speier-Pero (2015) investigate the impacts of full and partial price visibilities on the auction prices. Unlike the work of Elmaghraby et al. (2012), they reveal that the full price visibility provides a higher reduction in the procurement prices, compared to the partial price visibility. As the main reason for this result, the authors claim that the full price visibility helps overcome suppliers' cognitive barriers that inhibit determination of appropriate bids in real time. Haruvy and Katok (2013) examine the effects of bidders' quality transparency, price visibility, and the interaction between these two parameters on the auction prices. Their findings indicate that when each bidder exactly knows the owner of each bid submitted during the auction and the information about bidder quality is public, the buyer achieves a low surplus.

2.4. Summary of literature review findings

Table 2.3 compares our study with the existing literature in terms of the factors whose impacts on the buyer surplus have been studied. Our study differs from the existing studies since it is the first attempt, to the best of our knowledge, to empirically examine the joint impacts of the product category, the auction format, the 2008 financial crisis, and the number of bidders on the buyer surplus. For this examination, we collected a dataset from one of the leading e-auction providers in Turkey. The dataset includes the transaction details of 15458 auction events that were conducted with 16728 suppliers by employing three auction types, *Lot*, *Split*, and *Dutch*. It covers a period of ten years from March 2006 to March 2016. In the dataset, we classified the procurement projects into 14 different product categories by employing a keyword search algorithm. They are listed as follows: construction, chemical, indirect material, direct material, electrical works, service, logistics, health-care, metal, plastics, advertisement, manufacturing systems, technological equipments, and textile.

Additionally, from Table 2.3, it is observed that none of the studies in the current literature empirically examine how the group buying programs, contract types, and auction platform ownership affect the average decrease in the procurement prices. To fill this gap in the literature, we make use of the particular structure of our dataset. In the dataset, the auctions were conducted for two types of customers: (1) the group purchasing organization that is authorized to act as a purchasing agent for a group of individual firms and (2) the individual buyers that make purchases on their own. For managing the transactions between the buyer and auctioneer, three different contract types, *Percentage*, *Fixed*, and *Mixed*, have been used. Within the time covered by the dataset, the e-auction platform provider was acquired by one of its corporate customers. These specifications in the dataset allow us to address the impacts of group buying programs, contract types, and auction platform ownership on the buyer surplus. So, helping the understanding of the impacts of these factors on the surplus derived from auctions can be considered as another contribution of this study to the literature.

3. Research Framework and Questions

The economic significance of the reverse auctions has managed to attract the attention of the researchers in the operations management and economics fields. As a result, in the literature, the number of studies focused on the factors that have notable effects on the buyer surplus has increased significantly. In this research stream, typically, the impacts of *the number of bidders* (Millet et al. 2004, Mithas and Jones 2007, Park et al. 2012, Onur et al. 2012, Gurakar and Taş 2015, Raventós and Zolezzi 2015), *the number of submitted bids* (Millet et al. 2004, Mithas and Jones 2007, Pavel et al. 2013, Raventós and Zolezzi 2015), *the amount of auctioning item* (Bapna et al. 2003, Koppius et al. 2004, Pearcy and Giunipero 2006, Park et al. 2012), *the auction duration* (Mithas and Jones 2007, Raventós and Zolezzi 2015), *the reservation price* (Bapna et al. 2003, Kauffman and Wood 2006, Mithas and Jones 2007, Onur et al. 2012, Pavel et al. 2013), *the ranking information during the auction* (Millet et al. 2004, Mithas and Jones 2007, Elmaghraby et al. 2012, Tunca et al. 2014, Setia and Speier-Pero 2015), *the information about the auctioning item* - description, photo, etc.- (Koppius et al. 2004, Kauffman and Wood 2006, Stoll and Zöttl 2014), *the non-price attributes of the auctioning item* (Koppius et al. 2004, Engelbrecht et al. 2007, Haruvy and Katok 2013, Tunca et al. 2014, Stoll and Zöttl 2014, Moretti and Valbonesi 2015), and *the supplier incumbency* (Kauffman and Wood 2006, Mithas and Jones 2007, Tunca et al. 2014) have been addressed.

However, we are not aware of any studies that examine the joint impacts of the product category, the auction format, the number of bidders, and the 2008 financial crisis on the decrease in the auction prices. Additionally, to the best of our knowledge, none of the existing studies attempt to classify the product categories based on their impacts on the average decrease in procurement

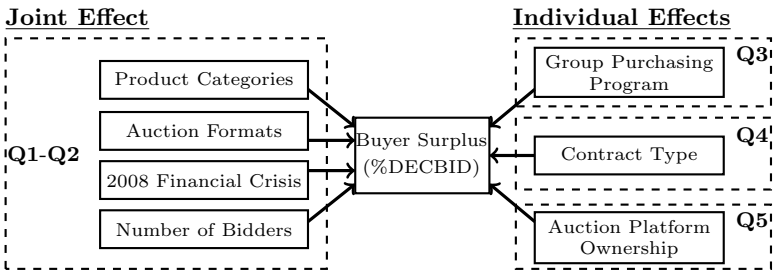


Figure 1 Research model

prices and analyze the impacts of the group buying, the e-auction platform ownership, and the type of contract between buyers and auctioneer on the average decrease on the procurement prices. To fill these gaps in the literature, we consider the following research questions:

- *Q1:* What are the effects of the product category, the auction type, the number of bidders, and the economic crisis on the decrease in the procurement prices with respect to the minimum of the initial submitted bids?

- *Q2:* How can the product categories be classified according to their impact on the decrease observed in procurement prices?

- *Q3:* Does the group purchasing programs yield a greater decrease in the procurement prices achieved at the end of an auction compared to buying individually?

- *Q4:* Are there differences among the decreases achieved when different contract types are used?

- *Q5:* Does having own e-auction platform yield more reduction in the procurement prices?

To address these research questions, we use a unique dataset from a third-party e-auction platform provider. The research model we employed in this study is summarized in Figure 1. We address the first research question by employing the Tobit model. With this approach, we study the joint effects of the product category, the auction type, the number of bidders, and the 2008 global financial crisis on the buyer surplus. For dealing with the second research question, we employ the Welch's ANOVA and Games-Howell Pairwise Comparisons tests and classify the product categories into three major groups. Lastly, the third, fourth, and fifth research questions are examined by using the student's t-test with unequal variances assumption. Hence, we investigate the individual effects of the auction platform ownership, the contract type, and the use of the group purchasing on the buyer surplus, namely without considering the other treatments effect.

4. Hypothesis Development

In this section, we develop nine hypotheses by utilizing the findings and conclusions of the existing studies and considering the experts' opinions. These hypotheses can be separated according to the two dependent variables included in our analysis: buyer surplus and procurement price.

4.1. Hypotheses regarding the buyer surplus

In the following paragraphs, we cover the hypotheses that are developed to analyze the impacts of the product categories, the auction types, the 2008 global financial crisis, and the number of bidders on the buyer surplus.

The impact of the product categories on the buyer surplus:

With growing attention on the use of the reverse auctions for the purchase of various products and services, firms become concerned whether this tool is equally effective in providing price reductions across the different product categories. In the literature, several studies also emphasize this emerging concern in practice and state the importance of an additional investigation regarding the effects of the product categories on the buyer surplus (Van den Poel and Leunis 1999, Lee 2009, Rao 2009).

However, despite the fact that the need for this research stream is highlighted, the number of studies that deal with the impacts of the product category on the buyer surplus has been quite scarce. Jap (2002) conducts an exploratory study on purchasing practitioners to ascertain what kind of products are appropriate for the reverse auctions. The author examines only a limited number of the maintenance and repair supplies. Based on this examination, the author claims that the online auctions perform well for the commodity products. Similarly, Manoochehri and Lindsy (2008), Tassabehji (2010), and Schoenherr and Mabert (2011) propose that the use of the reverse auction is advantageous in the purchase of commodity items, especially where the price is the primary consideration. The main intuition behind this result is that the number of suppliers willing and able to bid on the business is likely to be higher when the auctioned item is standard. Another reason that makes commodities ideal candidates for e-auctions is that the quality requirements are very easily fulfilled by the suppliers (Schoenherr and Mabert 2011).

Contrary to common belief, Carter et al. (2004) reveal that a complex item or service can be auctioned, as long as its attributes can be translated into unambiguous specifications. Pearcy and Giunipero (2006) also support this idea and report that the e-auctions are not only suitable for commodities or standardized items, it is also possible to use them for the purchase of the products with more complex attributes. However, both studies do not precisely specify which of the products in the other categories excluding the commodity category are suitable for the auctions.

To address this need in the literature, we study the effects of the different product categories on the buyer surplus and classify them based on their impacts on the average buyer surplus achieved through the e-auctions. The cost structure of a product is often different in each product category, resulting in different amounts of buyer surplus. More specifically, the cost structures of the products in the categories of chemical and logistics directly depend on commodity prices such as oil, natural gas, and bulk chemicals. Therefore, the marginal profits for the suppliers that operate in the

chemical and logistics categories are typically smaller than those for the suppliers in the other categories. For these categories, we expect that decreases in procurement prices achieved at the end of the auctions will be limited. The products in the categories of advertisement and manufacturing systems are mostly experience goods such as the design of a manufacturing system, the automation of a current system, and the creation of an ad campaign. Therefore, the suppliers that operate in the categories of advertisement and manufacturing systems tend to increase their marginal profits on the business to be auctioned. When the competition among the suppliers is increased by an e-auction the suppliers can exceedingly reduce their marginal profits to be successful at the end of the auction. As a result, we expect that the average decrease in the procurement prices is higher for the advertisement and manufacturing systems auctions than for the other product categories. Consequently, we posit that the product categories have a notable impact on the buyer surplus.

Hypothesis 1 *The product categories have a notable influence on the buyer surplus.*

If the product categories have an influence on the buyer surplus then they can be categorized based on their impact on the average decrease in procurement prices. Therefore, we propose the following hypothesis.

Hypothesis 2 *The product categories can be grouped based on their impacts on the average decrease in procurement prices.*

The impact of the auction type on the buyer surplus:
There is a significant literature that deals with the effects of the auction type on the auctioneer surplus within the traditional auction setting. Of the seminal analytical studies in this research stream, Vickrey (1961), Myerson (1981), and Bulow and Roberts (1989) reveal that the *English* and *Dutch* auction formats yield the same expected revenue to the auctioneer. This result, which also referred to as the revenue equivalence theorem in the literature, is obtained with the assumptions in which the bidders are risk-neutral and have independent valuations about the price. Additionally, Milgrom and Weber (1982) analytically compare the *English* and *Dutch* auction types in a setting where the winning bidder's pay-off may depend upon her personal preferences and the quality of the object being sold. The authors find that the *English* auction type yields a higher expected revenue for the auctioneer than the *Dutch* auction type under the assumptions that the bidders are risk-neutral and the price valuations are independent. Böheim and Zulehner (1996) also show that when bidders' valuations are affiliated, the *English* auction yields a higher expected revenue than the first-price, the second-price, or the *Dutch* auction types. For a problem setting where the private valuations are correlated and the bidders are risk-neutral, Wang (1998) derive that the *English* auction type outperforms the *Dutch* auction type in terms of generating revenue for the

auctioneer. It is important to note that the assumptions considered in these studies typically do not provide robust results. Accordingly, even if there is a slight deviation from one of the restrictive assumptions the given results could considerably vary (Leong 2008).

As formal theoretical predictions concerning the effects of the auction types on the auctioneer surplus strictly depend on model assumptions and often fail to capture the complexities in real-life auctions, research efforts have been devoted to establishing their empirical validity mostly using lab experiments and field observations (Hong et al. 2015). Soudry (2004) review the empirical and analytical studies that deal with the relative comparisons between the *English*, *Dutch*, first-price, and second-price auctions. The author highlights that within the forward auction context, the *English* auction is superior to the *Dutch* and first-price auctions. Bapna et al. (2009) study a dataset collected from one of the auction platform providers that offer forward auction service for its individual customers. They claim that the *English* auctions, on average, extract more revenue per unit than the *Dutch* auctions. With the empirical analysis of a dataset that covers the fish auctions in Denmark, Brendstrup and Paarsch (2006) derive that the *English* auction garners the auctioneer a higher expected revenue than the *Dutch* auction. Shachat and Wei (2012) use laboratory experiments to examine the relative performance of the *English* and first-price auctions. With this effort, they show that the average and variances of the prices achieved with the use of the first-price auction are lower than the ones achieved with the use of the *English* auction. By considering an experimental auction market selling a single risky object, Hong and Nishimura (2016) find that the *English* auction yields a higher seller revenue compared to the second-price auction.

With the review given in above, we conclude that none of the studies in the literature focus on the comparison of the effects of the *English* and *Dutch* auctions on the buyer surplus by considering the reverse auction setting. To address this need in the literature and to extend the findings in the forward auctions to the context of the reverse auctions, we address the effects of *English* and *Dutch* auctions on the buyer surplus. The difference between these two auction types mainly stems from the auction dynamics. More specifically, in the *English* auction, the bidders compete with each other by submitting successively lower bids for the item. With this structure, the *English* auction creates an iterative process that continues until a price is reached where there is just a single bidder who is willing to supply the auctioning item. However, in the *Dutch* auctions, the price is monotonically increased by the auctioneer until there is a single bidder who is willing to supply at the currently announced price. More specifically, in the Dutch auction, a bidder has to guess when to bid, however, there is no such guessing in the English auction and a bidder can stop when his or her value is reached. This bidding rule difference causes the fact that the competition among the participants is less in the *Dutch* auctions compared to the *English* auctions (Ausubel 2003, Salant 2014). As a result of this fact, consistent with the previous findings in the forward

auction literature, we expect a greater buyer surplus in the *English* auctions compared with the *Dutch* auctions. Thus:

Hypothesis 3 *English auctions yield more buyer surplus compared to Dutch auctions.*

Auction types can also be classified on the basis of the number of suppliers to be used for purchasing the item at the end of the auction. At a basic level, this involves a choice between competition on a winner-take-all basis or competition that allows for split awards among a number of bidders (Anton et al. 2010). In practice, the auctions in which a winner supplies all the auctioned items are referred to as *Lot* auctions whereas the auctions in which multiple suppliers provide the auctioned items are called as *Split* auctions.

There exists a vast literature focusing on the effect of the *Lot* auctions on the buyers within the reverse auction setting. The studies in this research stream claim that the transaction and administrative costs were reduced due to the lot-award structure (Jap 2002). Additionally, with the lot-award structure, production economies of scale are obtained in the auctions. Based on these facts, Jap (2007) and Aloini et al. (2012) reveal that in industrial procurement, the auctions with the lot-award structure yield more price reductions than the auctions with the split-award structure. The results derived from these studies depend on the expert ideas or surveys rather than an econometric analysis. Accordingly, we believe that an econometric analysis addresses the effects of the award structure on the buyer surplus would contribute to the literature by showing whether the intuition in practitioners' minds is coherent with the results that have been obtained in practice.

For this purpose, in this work, we focus on the effects of the award structure on the buyer surplus. From the discussion and drawing on the results in above studies, a higher buyer surplus is expected to be obtained in the *Lot* auctions compared with the *Split* auctions.

Hypothesis 4 *Lot auctions yield more buyer surplus compared to Split auctions.*

The impact of the 2008 global financial crisis on the buyer surplus:
Global crises typically generate impetuous changes in the market demand, because, during the downturn periods, many companies dramatically reduce purchases and cut inventories while others temporarily close or go out of business. For instance, the economic downturn that began during the fall of 2008 has notably affected many firms' revenues, with some of them reporting decreases in sales of 30% and more (Krause and Ellram 2014). Dooley et al. (2010) also report that the crisis in 2008 results in a 3.2% sales decrease across the entire manufacturing sector in the U.S. compared with the previous year. These dramatic effects of the economic downturns provide significant challenges to all the parties in the supply chain, especially the suppliers.

During the economic recession periods, the suppliers often bear the costs of a downturn in demand through an ability to use accumulated resources and/or to absorb fixed costs (Morris and Imrie 1992). More specifically, the economic recession periods would likely force the suppliers to push down their prices in order to sell the excess capacities resulted due to crimping demand from deteriorating economic conditions. In such a case, the revenues that could be obtained through the e-auctions would be more important for the suppliers, because, the reverse auctions provide to the suppliers a chance of reaching new buyers and an outlet to sell the excess capacity (Schoenherr et al. 2012).

This fact naturally increases the competition among the suppliers participating in the auctions when there exists an economic downturn in the market. So, the suppliers struggling to find a market for their product due to an economic recession would lower the price as much as they can do in order to be the winner at the end of auction. In fact, during the economic recession periods, many buyers use the reverse auctions as a tactical weapon to drive supplier prices down and they expect to gain more benefit than the time when there is no economic recession (Hutt and Speh 2005).

From this discussion and drawing on the results regarding the effects of economic downturn periods on the suppliers, we posit the following hypothesis:

Hypothesis 5 *The 2008 global financial crisis led to an increase in the buyer surplus.*

The impact of the number of bidders on the buyer surplus:

In the case of procurement auctions and contract bidding, several empirical studies report that higher number of bidders lowers purchasing price. For instance, Pearcy and Giunipero (2006) and Park et al. (2012) state that an increase in the number of bidders participating in the auction leads to an increase in the buyer surplus as it intensifies the competition among the bidders in the online market. Smeltzer and Carr (2003) and Wyld (2011) propose that a minimum of five viable bidders is needed to lower purchasing prices by creating a competitive bid environment. Along similar lines, Millet et al. (2004) empirically show that the highest price reduction results are obtained by inviting at least five or six, up to a maximum of 13.

There are also a number of analytical works that are devoted to the analysis of the impact of the number of bidders on the buyer surplus. Ağralı et al. (2008) study a logistics spot market in which a number of firms asking for transportation and two types of carriers are matched through the reverse auctions. They show that a reduction in the auction prices is positively associated with an increase in the number of bidders. Chen (2012) examines the coordination mechanism for supply chain with multiple competing suppliers in the electronic market. The author denotes that the auctions where the number of bidders is high result in a lower purchasing price. Karabağ and Tan (2017) develop an analytical model to analyze the impact of the existence of an e-auction provider in the market

on the buyers and suppliers. Consistent with the previous results, their numerical analysis indicate that as the number of bidders increases in the auctions the purchasing price reduces.

All the studies discussed above implicitly reveal that the positive impact of the existence of an extra bidder in the auction does not depend on how many participants have already been in the auction. That is, the marginal effect of having one more bidder in the auction on the buyer surplus is constant. However, one can expect that when the total number of bidders in the auction is small an increase in the number of bidders has a higher positive impact on the buyer surplus as compared to when the total number of bidders in the auction is large. Because its positive impact on the competition level in the auction is higher for the setting where the total number of bidders participating in the auction is small than for the setting where the total number of bidders participating in the auction is large (Lalive et al. 2017). So, we believe that the positive impact of having an extra supplier in the auction on the buyer surplus decreases as the number of bidders is getting larger and posit the following hypothesis:

Hypothesis 6 *The positive impact of having one more bidder in the auction on the buyer surplus decreases as the number of bidders is getting larger.*

4.2. Hypotheses regarding the procurement prices

In the following paragraphs, we cover the hypotheses that are developed to examine the impacts of the group purchasing, the contract type and the ownership of the e-auction platform on the average decrease in procurement prices.

The impact of the group purchasing on the procurement prices:

Group purchasing is the practice of several buyers forming a consortium by gathering through a third-party in order to negotiate with the suppliers at a more favorable price. For the buyers, it typically provides larger volume discounting and cost-saving opportunities through economies of scale. The third-party typically charges the buyers based on a fee that is determined according to the value of the item being purchased and it generally offers the group purchasing services to its corporate customers through the e-auctions.

The notion of group purchasing and the motives that drive the buyers and suppliers to use the group purchasing programs are well-established in the works of Schotanus et al. (2010) and Wei et al. (2011). Nollet and Beaulieu (2003) perform over 70 interviews with the purchasing experts who work in the health-care sector and identify the critical factors impacting on the development of purchasing groups. Ghaderi et al. (2012) empirically study the effects of a successful group purchasing program on the logistics activities operated by a group of small- and medium-sized food enterprises. Their results show that a reduction of 10% to 30% in the logistics cost can be achieved

when the group purchasing option is used instead of using the individual buying option. Similarly, the benefits of group purchasing programs to the corporate customers are well discussed in the work of Tan (2014) by introducing an industrial case study from Turkey.

Additionally, in the operations management literature, there exist several analytical studies that deal with the notion of group purchasing. Keskinocak and Savaşaneril (2008) study the underlying economics behind the collaborative procurement programs and the effects of collaboration on the buyer and supplier profitability. The authors ascertain that the buyers are always willing to collaborate if they have no limitations on procurement quantities, such as uncapacitated storage limit. Chen et al. (2009) and Hu et al. (2012) analytically show that a group purchasing programs can have positive and significant impacts to the buyer surplus when the certain conditions satisfied. Similarly, Karabağ and Tan (2017) analytically show that under the certain conditions, a group purchasing organization helps buyers and/or suppliers to mitigate demand and price risks and so it could be beneficial for all parties in the market.

To the best of our knowledge, we are not aware of any empirical studies that focus on whether the findings derived from the analytical models and surveys are coherent with the practice. With the analysis conducted in our work, we aim to fill this gap in the literature. Consistent with the previous findings, we expect that the purchases conducted with the group purchasing options, on the average, results in a lower price than the ones conducted with the individual buying options. Thus, we posit the following hypothesis:

Hypothesis 7 *The average purchasing prices achieved with the group purchasing options is lower than the one achieved with the individual buying option.*

The impact of the contract type on the procurement prices:
In practice, the market maker typically charges its corporate customers based on three contract types, *Fixed*, *Percentage*, and *Mixed* in exchange of the use of the e-auction platform. In the *Fixed* contract type, the market maker asks the buyers to pay a fixed fee as a member of its network and/or a user of the platform. The market maker generally receives the payment from the buyers in advance as the payment amount is independent of the number of transactions being processed in the online marketplace. The fixed fee contracts are typically used for encouraging the buyers to use the online marketplace and for reducing the possible extra costs associated with the tax issues (Hartmann 2002). In the *Percentage* contract, the market maker generally charges the buyers based on a per-transaction commission as a non-decreasing function of the order quantity being transacted in the auction or a per-transaction commission as a non-decreasing function of the wholesale price and order quantity (Jin and Wu 2001). In practice, the former is referred as a scheme based on the commission charged by the order quantity whereas the latter is called as a scheme based on

the commission charged by the transaction volume. It is common to pay between 0.25 and 5% of either the transaction volume or the order quantity. The pricing schemes that depend on the transactions in the auction introduce an additional financial risk for the buyers, as the margin for the exchange is dependent on the product pricing above costs instead of fixed transaction fees (Hartmann 2002). In the *Mixed* contracts, the buyers pay a fixed service fee as well as a commission based on the transactions in the auction. Essentially, it combines features from the *Fixed* and *Percentage* contracts.

Even though the buyers use the e-auction platform provided by the third-party, they generally manage the RFQ processes on their own. In the RFQ process, the buyers ask the participating suppliers to submit their best initial offers for the auctioning item. With the minimum of the bids received in the RFQ process, the buyer or the auctioneer typically measure the auction efficiency. In fact, in some cases, this efficiency measure is used to determine the payment fee for the buyers who use the e-auction platform with the *Percentage* contracts. In such a case, the buyer has a strong incentive to encourage the suppliers to lower their initial bids. Because, the efficiency appeared at the end of the auction can relatively be decreased with this effort and the buyer pays less service fee to the auctioneer. Additionally, as the buyer put an extra effort to further reduce the suppliers' initial bids submitted in the RFQ process, she would not lose her buyer surplus to be obtained at the end of auction. From this discussion, we expect that the auctions conducted with the *Percentage* contracts have a lower average decrease in procurement prices compared with the ones conducted with the *Fixed* contracts. Thus, we consider the following hypothesis:

Hypothesis 8 *Percentage contract type yields a lower average decrease in procurement prices compared to Fixed contract type.*

The impact of the e-auction platform ownership on the procurement prices:
The buyers can employ either a third-party e-auction provider or its own infrastructure to conduct the reverse auctions. In most of the time, establishing a private auction infrastructure does not only require a high investment in the information technology but also require an experience and a large supplier base to manage and operate the online marketplaces. Additionally, using a private auction platform may lead a deteriorating buyer and supplier relationships. Because, once a buyer runs its own auction platform, the suppliers could become skeptical as to the legitimacy of bids or come to believe that the auction platform is being manipulated by the owner (Wyld 2011). The discontent among suppliers for the auctions conducted with the private platforms starts adversely affecting suppliers' bidding behaviors. In the literature, this issue is referred to as the buyer's opportunism. To avoid these possible risks, the buyers mostly prefer to use the specialized third-party providers, rather than establishing and employing their private infrastructures.

In the literature, the opportunism issue has received increasing attention in recent years. Tangpong et al. (2010), and Handley and Benton Jr (2012) provide a detailed overview regarding the opportunism issue addressed within the supply chain management and reverse auction literature. Based on a survey study, Jap (2002) ascertains that the suppliers' suspicions of opportunism increase after the open-bid auction, because, the suppliers consider this auction type as an exploitative and unfair tool. Manoochehri and Lindsy (2008), Tassabehji (2010), and Spann et al. (2018) report that suppliers typically view e-auctions as a tool that increases buyer opportunism and that damages their relationships with the buyers. The authors also emphasize that the buyer surplus achieved with the use of auctions tend to decrease due to the suppliers' perceptions of opportunism. With a lab experiment, Gattiker et al. (2007) find that the e-auctions lead to a lower level of trust among the suppliers compared to the face-to-face negotiations. Jap (2007) conducts a survey analysis and reveals that as the number of suppliers and the amount of auctioning item increase the opportunism suspicions among the suppliers decreases. By conducting a laboratory experiment, Carter and Stevens (2007) observe that when the suppliers' perceptions of opportunism increase the buyer profit tend to decrease. Wyld (2011) suggests to the use of the third-party e-auction providers to avoid these issues. The author reveals that the involvement of the third-party provides a neutrality and legitimacy to the reverse auctions, and thus, the trust factor among the parties in the market is enhanced. The author also claims that the buyer can improve its surplus by using the platform provided by a third-party firm rather than using its own platform.

To the best of found knowledge, we are not aware of any empirical studies that focus on whether the findings derived from the surveys are coherent with the practice. By filling this gap, we aim to contribute to the understanding of the effect of the auction platform ownership on the buyer surplus. Consistent with the findings in the previous studies, we posit that the average decrease in procurement prices is higher for the auctions conducted through the third-party auction provider than for the auctions conducted through the private auction platform.

Hypothesis 9 *The average decrease in procurement prices is higher for the auctions conducted through the third-party auction provider than for the auctions conducted through the private auction platform.*

5. Data Description

This study is based on a third party auction provider that offers online marketplace services to its corporate customers. The company has 131 corporate customers from different sectors and provides them to auction solutions for over 1500 different products and services. Its supplier network encompasses approximately 17000 providers from the different parts of the world. The platform provider was established in 2001 and operated as an independent company until June 2013 when

it was acquired by one of its corporate customers. After this acquisition, the platform provider has begun to offer not only services related to e-auction solutions but also collective procurement events.

5.1. Auction data

The dataset analyzed in this work is gathered from the online auction platform. Table 5.1 presents the data structure. The raw dataset includes all the variables presented in Table 5.1, except for the product category, the buyer type, and the crisis variables.

Collected Data		Description
Auction Number	:	A unique identity number given for each auction.
Starting Date and Hour	:	Starting date and hour of the auction.
Finishing Date and Hour	:	Finishing date and hour of the auction.
Auction Duration (DURATION)	:	Duration of the auction in minutes.
Buyer Name	:	Name of the firm that will buy the product from the bidders at the end of auction.
Product Name	:	Name of the product that will be bought at end of auction. Technical specifications for the product are also given here.
Number of Bids (BIDS)	:	The number of bids submitted during the auction.
Number of Invited Suppliers (INVITED)	:	The number of suppliers which are invited to the auction.
Number of Participated Suppliers (BIDDERS)	:	The number of suppliers which participated in the auction among the invited ones.
Auction Type	:	There are three auction types that are administered by the auctioneer: *Lot*, *Split* and *Dutch*.
Contract Type	:	There are three contract types that are used by the auctioneer: *Fixed*, *Percentage* and *Mixed*.
RFQBID	:	The minimum of bids in the RFQ process. Unit of this variable is 10000 USD.
Resulting Bid	:	Winning bid at the end of auction. It is kept in USD.
Decrease in RFQBID	:	The difference between RFQBID and Resulting Bid. It is kept in USD.
%DECBID	:	Relative difference between RFQBID and Resulting Bid, $\frac{100\,(\text{RFQBID} - \text{Resulting Bid})}{\text{RFQBID}}$.
Added Data		**Description**
Product Category	:	The auctions comprise of 14 different categories: construction, chemical, indirect material, direct material, electrical works, service, logistics, health-care, metal, plastics, advertisement, manufacturing systems, technological equipments, and textile.
Buyer Type	:	Indicator variable shows the type of buyer. There are two different buyer types such as the GPO that acts as a purchasing agent for a group of individual firms and the individual buyers that make purchases on their own. In the buyer type variable, the individual buyers are coded as 1 whereas the GPO is represented by 0.
Crisis	:	The global financial crisis of 2008 and its effects are controlled by this variable. The variable is equal to 1 for the years 2008 and 2009. Otherwise, it is zero.

Table 2 Main structure of the dataset

Our dataset consists of 130 different individual buyers and a group purchasing organization. All the procurement events are mapped into two classes depending on the buyer type in the dataset. We observe that 89% of the 15458 auction events were conducted for the individual buyers and 11% of the auction events were executed for the GPO. With this structure of the dataset, we are able to investigate the effects of the group purchasing programs on the average decrease in procurement prices achieved due to the auctions.

The dataset contains more than 1500 different products ranging from a hand tool that was bought at a price of 150 USD to a logistics project that was given to a bidder that offered a price of 33 million USD. Although the name of the product and its technical specifications are covered by the raw dataset, there is no information about the product categories. To address this issue, the 15458 auction events are classified into 14 product categories by using a keyword matching algorithm. The keywords of medicine, hospital, medical, prosthesis, surgery, and patient are some of the examples used for determining the products in the health-care category. Transportation, cargo, shipping, road, airline, maritime, and partial freight are employed to determine the products in the logistic category. As a result of this effort, each product in the dataset is mapped into one of 14 different categories. We also match the product categories considered in our work with the ones proposed as the United Nations Standard Products and Services Code. The details can be found in Table 9, which is given in Appendix. The structure of the dataset allows us to examine the impact of the product categories on the buyer surplus obtained with the use of e-auctions.

Following the global financial crisis of 2008, the effects of the economic crisis were felt deeply in all the countries of the world and the majority of firms witnessed major declines in output, profitability, and trade (Alfaro and Chen 2012). To observe how this phenomenon affected the surplus of the buyers that used e-auctions, we investigate the effects of the years 2008 and 2009 separately. To do so, we create the Crisis variable in such a way that it is equal to 1 for the years 2008 and 2009 whereas it is 0 for the other years.

	Auction Type				
Product Category	*Lot*	*Split*	*Dutch*	**Total**	**% Percentage**
Direct Material	3285	253	812	4350	28.1%
Construction	3053	69	335	3457	22.3%
In-Direct Material	2181	159	109	2449	15.8%
Health-Care	61	1677	2	1740	11.3%
Service	563	30	106	699	4.5%
Electrical Works	483	21	80	584	3.8%
Metal	368	18	35	421	2.7%
Technological Equipments	316	25	59	400	2.6%
Textile	321	47	20	388	2.5%
Logistics	204	124	11	339	2.2%
Advertisement	244	11	26	281	1.8%
Chemical	109	12	41	162	1.1%
Manufacturing Systems	80	13	23	116	0.8%
Plastics	57	12	3	72	0.5%
Total	11325 (72.9%)	2471 (16.4%)	1662 (10.7%)	15458	100%

Table 3 Frequency table for the number of auctions organized in different the product categories and the number of auction formats used in the procurement events

Table 5.1 shows the distributions of the number of auctions organized in the different product categories and the number of auction formats used in the procurement events. Direct material

auctions take the majority with 28% of all auctions, followed by auctions for construction with 22% and indirect material auctions comprising 16%. In the dataset, three different auction formats are used by the auctioneer: *Dutch*, *Lot*, and *Split*. As Table 5.1 indicates, *Lot* is the most frequently used auction method, accounting for 73% of all auctions. *Split* and *Dutch* constitute 16% and 11% of all auctions, respectively. Since the dataset includes *Dutch*, *Lot*, and *Split* auction types it allows us to address the Hypotheses 3 and 4.

In the dataset, there are also three contract types employed to manage the relationship between the buyers and the auctioneer. These are *Percentage*, *Fixed*, and *Mixed* contracts. The numbers of *Percentage* and *Fixed* contract types that are used in the e-auction events are 12004 and 359, respectively. In addition, the *Mixed* contract type was used in 3095 auctions. Due to this structure of the dataset, we are able to address the Hypothesis 8.

5.2. Auction procedure

In the purchasing organization, the procedure for an e-auction starts with the preparation of the request for quotes (RFQ) process. RFQ is a typical process that includes the determination of the list of potential suppliers to be invited to participate in the auction event, the submission of the detailed specification of the item to be auctioned, and the declaration of the auction details. The specifications of the product and the list of suppliers are determined by the buyer. When the buyer does not define the list, the participants are proposed by the auctioneer considering the buyer requirements and the characterization of the product. Under this setting, the buyer reviews the auctioneer's list of the proposed suppliers and prunes the list as required.

Once the approval from the buyer for the product specifications and the list of the suppliers are received, the auctioneer provides a recommendation on what type of the auction should be used for the item to be auctioned. With this recommendation, the auctioneer fully describes the auction parameters, such as the bid decrement and the starting time. The last decisions on each auction parameter and whether to implement the proposed auction format are given by the buyer.

After the buyer's decisions on the auction format and its parameters, the required settings in the e-auction platform are specified by the auctioneer. Next, the auctioneer invites all of the suppliers in the pre-specified list to participate in the e-auction. Each invited supplier gets the details of the e-auction and informs the auctioneer whether he is willing to participate in the auction.

Before the e-auction starts, the buyer requests the participating suppliers to submit their best initial offers for the auctioning item. Each participating supplier is obliged to participate in these negotiations and to respond to the request of submitting an initial offer.

The initial bids are received from all of the participating suppliers before starting the e-auction and the smallest of the initial bids, referred to as RFQBID, is obtained. Since the online system is

used while conducting this process, the auctioneer also has the information on the initial offers and RFQBID. With this effort, the buyer and the auctioneer determine the price of the item before executing the e-auction. In the dataset, the difference between the prices before and after the e-auction refers to the efficiency of the e-auction. In this study, we focus on how this difference is affected by the 2008 global financial crises, the product category, the auction type, and the number of bidders.

In *Percentage* contracts, the buyer may put an extra effort to reduce the initial offers because he will pay the service fee to the auctioneer according to the decrease in the minimum of the initial submitted bids. On the other hand, the suppliers may submit their best initial bids since they expect that there will be a high level of competition in the auction when the number of bidders is high. These phenomena may lead the fact that the decrease in the procurement price with respect to RFQBID will be quite small or even zero. That is, since the initial submitted bids are in fact good offers, there is a little room for the decrease that may be achieved at the end of the auction.

Once the RFQBID is determined, the buyer starts the e-auction. During the auction time frame, all of the participants submit their bids electronically. Each submitted bid has a time stamp and only the bids that conform to the auction rules are considered as valid. The auctioneer is responsible for operating all of the steps without any technical or synchronization problems. After following the pre-specified rules for the chosen auction format, the auction terminates. The summary results of the auction and the winning bidder are submitted to the buyer as a single report.

5.3. Auction formats

The dataset consists of three auction types, *Dutch*, *Lot*, and *Split*. In a *Dutch* auction, the auctioneer begins by calling out an initial price low enough so that presumably no bidder is interested in selling the item at that price. In our dataset, the initial price in *Dutch* auctions is generally set to lower than 25% of RFQBID. The initial price is gradually increased at the fixed time intervals until one of the bidders agrees to sell the item at the stated price.

Lot and *Split* auctions are the reverse auction mechanisms where more than one items can be auctioned at a time. In a *Lot* auction, all of the auctioning items are considered as a single one. Therefore, each submitted bid should include a single price for all items. However, in *Split*, the bidder can submit a different price for each auctioning item so that a different auction for each item is executed simultaneously. Accordingly, there is only one winning bidder in a *Lot* auction whereas there may be more than one winner in a *Split* auction.

For *Lot* and *Split* auctions, except the difference in the rules for determining the structure of award, the auction rules are the same as the rules of the *English* auction. Therefore, one can consider the *Split* auction as a special case of the *Lot* auction. In an *English* auction, an auctioneer starts

requesting bids from all of the participants. During the auction, each participant can only bid by meeting the rule proposed by the auctioneer. More specifically, in our dataset, the auctioneer only accepts bids that are smaller than the current lowest one. By considering this rule, the bidders dynamically submit successively lower bids for the item. The auction stops when no bidder is willing to decrease its bid below the lowest standing bid.

5.4. Descriptive statistics

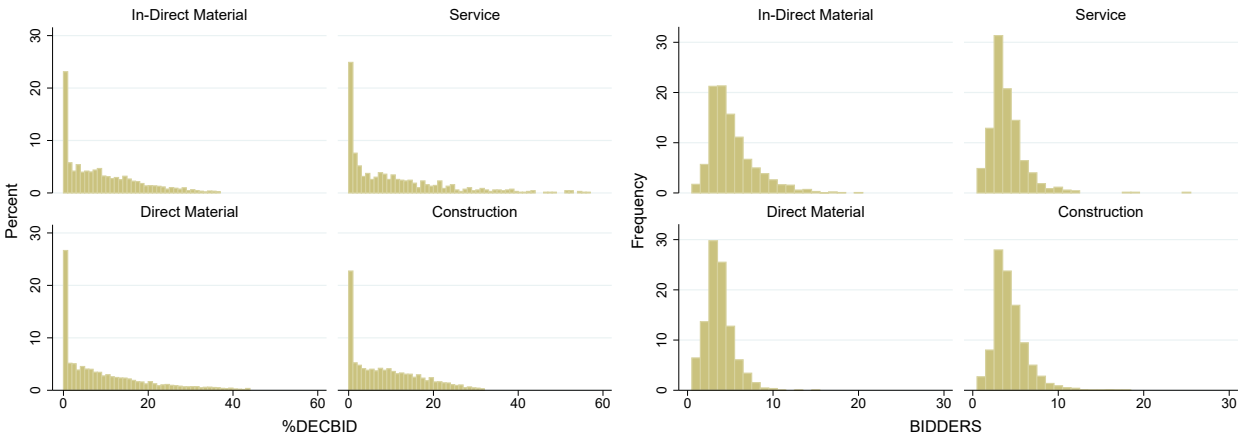
The descriptive statistics for the minimum of bids submitted in the RFQ process (RFQBID), the relative difference between RFQBID and the resulting bid (%DECBID), the auction duration (DURATION), and the number of bids submitted during the auction (BIDS) are given in Table 5.4.

	RFQBID (10000$)		%DECBID (percentage)		DURATION (minutes)		BIDS (number)	
Product Category	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Advertisement	16.1	28.8	13.3	11.7	49.2	30.3	58.8	70.7
Plastics	14.3	45.2	12.9	11.3	44.7	23.8	29.1	33.3
Manufacturing Sys.	20.5	50.9	11.5	9.3	48.7	30.8	36.6	42.4
Service	31.7	75.9	10.5	11.8	53.1	36.6	45.5	56.1
Textile	12.4	26.2	9.6	8.6	54.5	27.5	45.4	40.1
Direct Material	12.0	33.2	9.4	10.2	46.7	153.0	26.4	35.9
In-Direct Material	21.5	132.2	8.9	8.6	48.0	43.8	40.3	52.3
Construction	28.3	91.1	8.9	8.0	50.1	38.1	39.8	35.8
Metal	21.6	43.8	8.6	9.9	44.8	23.8	27.4	26.0
Technological Eq.	34.5	207.3	8.6	8.7	48.4	79.5	29.3	30.4
Electrical Works	26.8	111.5	7.5	6.9	49.0	29.9	33.9	32.9
Logistics	108.2	202.4	4.9	5.2	80.7	58.7	81.3	101.0
Chemical	84.6	258.1	4.2	4.5	41.6	29.0	24.1	38.2
Health-Care	2.8	9.0	3.3	2.9	53.0	29.4	64.6	52.4
Total	21.4	93.7	8.4	9.0	48.6	41.5	39.5	46.7

Table 4 Descriptive statistics for the lowest bid submitted in the RFQ process, the percentage decrease in RFQBID, the auction duration, and the number of bids

The overall average and standard deviation of %DECBID are 8.4% and 9%, respectively. That is, on the average, the e-auction platform yielded a 8.4% decrease in procurement prices with respect to the minimum of the initial submitted bids. Table 5.4 indicates that the average %DECBID is relatively higher for the advertisement, plastics, and manufacturing systems categories than for the others. Table 5.1 shows that although there is an opportunity of achieving a large decrease in procurement prices by using e-auctions, buyers do not frequently use e-auctions for the products in the advertisement, plastics, and manufacturing systems categories. On the other hand, for the categories of chemical, health-care, and logistics, the average %DECBID is relatively small compared to that in the other product categories. With these arguments, one can conclude that the product category may have an effect on %DECBID and that the product categories may be classified based on the level of %DECBID.

In all product categories, %DECBID has a positively skewed distribution and the number of observations at zero is considerably higher than that at other values. In 2428 auctions, RFQBID



(a) (b)

Figure 2 **For the categories of indirect material, service, direct material, and construction, (a) the histograms of the percentage decrease in RFQBID and (b) the histograms of the frequency of the numbers of bidders**

is the auction price and the owner of this bid is the winner of the auction. Therefore, %DECBID equals zero in these auctions. Figure 2(a) depicts the histograms for indirect material, service, direct material, and construction categories. It shows that 23% of indirect material auctions yield no decrease in RFQBID whereas %DECBID is zero in around 25% of auctions executed for products in the service category. In 27% of direct material auctions and 22% of construction auctions, a decrease in RFQBID is not observed.

Figure 2(b) shows that in the indirect material, service, direct material, and construction categories, the number of bidders follows a slightly right-skewed distribution and the average number of bidders are between 3 and 4. We observe that the distributions of the number of bidders in the other categories are also right-skewed as the ones depicted in Figure 2(b), however, the average number of bidders participating in the auctions are mostly greater than 4. For the sake of brevity, they are not presented in here.

6. Methodology

In this section, we specify the statistical methods employed in the analysis of the hypotheses and provide the reasons why we choose these tools for the analysis.

With Figure 2(a), we have spotted that our dataset contains a significant proportion of observations in which there is no decrease in RFQBID, i.e., %DECBID=0. These observations comprise around 16% of our dataset. The classical methods such as linear regression model probably do not account for the piling up of zeros and could result in biased estimates for the effects of the product category, the auction type, the 2008 global financial crisis, and the number of bidders on the buyer surplus. To avoid this issue that may arise in the analysis of the Hypotheses 1, 3, 4, 5 and 6, we utilize the standard Tobit model (Tobin 1958). The results related to the model are discussed in Section 7.1.

In the standard Tobit framework, the dependent variable can take on the value of zero with positive probability but is a continuous random variable over strictly positive values. This special distribution characteristic of the dependent variable is referred as the corner solution response. To develop a model that accommodates the corner solutions, Tobin (1958) introduces a latent variable, y_i^*, that satisfies the classical linear model assumptions for a given sample. By making use of the latent variable, the standard Tobit model is expressed as

$$y_i = \begin{cases} y_i^* & \text{if } y_i^* > 0 \\ 0 & \text{if } y_i^* \leq 0 \end{cases} \quad \text{where} \quad y_i^* = \mathbf{X_i}\boldsymbol{\beta} + \epsilon_i, \quad \epsilon_i | \mathbf{X_i} \sim Normal\left(0, \sigma^2\right). \tag{1}$$

y_i is the dependent variable and $\mathbf{X_i}$ is the vector of the independent variables. In addition, $\boldsymbol{\beta}$ is the vector of the coefficients and ϵ_i is the error term for the i^{th} observation. The Tobit model proceeds by applying maximum likelihood estimation to all data points including the zeros.

In the Tobit model, the estimated coefficients are the partial effects of the explanatory variables on the latent variable, y_i^*. The partial effect of the k^{th} explanatory variable, x_k, on the dependent variable, y_i, depends on $\mathbf{X_i}$ throughout calculated probability distribution associated with the explanatory variables, but always has the same sign as the corresponding Tobit coefficient. In other words, since the derivative calculations performed to obtain the partial effects result in the different value for each $\mathbf{X_i}$, the Tobit coefficients do not represent partial effects of the explanatory variables on the dependent variable. Additionally, the Tobit coefficients imply the direction of the relationship between the corresponding explanatory variable and the dependent variable due to the fact that the partial effects of explanatory variables have the same sign as the corresponding Tobit coefficient. For more detailed discussion on the issue in the estimation of the partial effect of x_k on y_i, we refer the reader to Wooldridge (2002).

To overcome the issue in the estimation of the partial effect of x_k on y_i, the method of Average Partial Effects (APE) is used following the work of Wooldridge (2002). For the case in which x_k is a discrete variable, the partial effect of increasing x_k from a given value, say h to $h+1$, is stated

$$APE = N^{-1} \sum_{i=1}^{N} \left(\Phi\left(\frac{\mathbf{X_i'}\hat{\boldsymbol{\beta}}}{\hat{\sigma}} \right) \mathbf{X_i'}\hat{\boldsymbol{\beta}} + \hat{\sigma}\phi\left(\frac{\mathbf{X_i'}\hat{\boldsymbol{\beta}}}{\hat{\sigma}} \right) - \Phi\left(\frac{\mathbf{X_i}\hat{\boldsymbol{\beta}}}{\hat{\sigma}} \right) \mathbf{X_i}\hat{\boldsymbol{\beta}} - \hat{\sigma}\phi\left(\frac{\mathbf{X_i}\hat{\boldsymbol{\beta}}}{\hat{\sigma}} \right) \right) \tag{2}$$

where the terms with hat are the estimates obtained from the data and N is the number of observations. $\Phi(.)$ and $\phi(.)$ are the cumulative distribution and the probability density functions of the standard normal distribution, respectively. $\mathbf{X_i'}$ is the vector at which x_k equals $h+1$ whereas $\mathbf{X_i}$ is the vector at which x_k is equal to h. For both vectors, the remaining explanatory variables equal their own values as observed at the i^{th} data point.

Since the product categories are coded as categorical variables in the Tobit model the coefficients regarding these variables are estimated according to a base category. So, the coefficients report

the relative difference that could be obtained when the auction is conducted in another product category instead of the base one. Due to this fact, the Tobit coefficients only give a rough idea which of the product categories can be considered in the same group. To classify the product categories in a correct manner, each category should be compared with each other and the groups should be formed according to these results. Since the product categories do not satisfy the assumptions of equal variances and of equal sample sizes the tests to be used in the classification analysis should be robust against these issues. Therefore, for the pairwise comparisons conducted across the product categories, we use Games-Howell test (Games and Howell 1976) that is rather similar to Tukey's test in its formulation, but, does not assume equal variances and sample sizes. Additionally, before conducting pairwise comparisons tests, we should assure that the average percentage decrease in at least one product category is different than the ones in the others. To perform this analysis, we utilize Welch's ANOVA test (Welch 1951) that is a modification of one-way ANOVA allowing for non-homogeneous variances across the groups. With the Games-Howell and Welch's ANOVA tests, we evaluate the Hypothesis 2 and present the corresponding results in Section 7.2.

When the buyer type, contract type, and the ownership of the e-auction platform are treated as an exogenous variable in the standard Tobit model, the number of observations would not be sufficient to get unbiased and consistent estimates of the coefficients. Specifically, the number of observations would be zero for some of the combinations of the categorical variables. Therefore, we use two sample student t-test with unequal variances assumption while assessing the Hypotheses 7, 8, and 9, which respectively consider the possible impacts of the buyer type, contract type, and the ownership of the e-auction platform on average decrease in procurement prices. The results related to the tests are discussed in Sections 7.3, 7.4, and 7.5.

7. Empirical Analysis

In this section, the results of the statistical analyses conducted to address the hypotheses stated in Section 4 are presented.

7.1. Analysis of the factors affecting the buyer surplus

For the analysis of the effects of the product category, the auction type, the 2008 global financial crisis, and the number of bidders on the buyer surplus, we employ the standard Tobit model and present results in Table 7.1. The inflation rate, days when the auction conducted, and currencies used in the auction have been considered as the control variables in the Tobit model. However, we observe that the coefficients corresponding to the inflation rate, days when the auction conducted, and currencies used in the auction have not been statistically significant. More importantly, their inclusion in the model has not changed the estimates of explanatory variables. Due to these facts, we have ignored these control variables and presented only the results of the simplest model.

Variables/Method	Standard Tobit Model with MLE	
	Dependent variable:%DECBID	Average Partial Effects (*APE*)
Auction Type		
Lot	4.09^{***} (0.26)	3.42^{***} (0.64)
Split	1.32^{***} (0.40)	1.01^{***} (0.33)
Product Category		
Plastics	4.98^{***} (1.39)	4.10^{***} (1.23)
Manufacturing Sys.	4.81^{***} (1.02)	3.95^{***} (0.82)
Advertisement	4.20^{***} (0.78)	3.42^{***} (0.65)
Service	2.66^{***} (0.61)	2.11^{***} (0.53)
Direct Material	1.86^{***} (0.39)	1.46^{***} (0.32)
Technological Eq.	1.28^{*} (0.67)	0.98^{*} (0.50)
Textile	1.09^{*} (0.61)	0.86^{*} (0.47)
Construction	0.59 (0.38)	0.45 (0.30)
Metal	0.25 (0.63)	0.19 (0.47)
In-Direct Material	-0.17 (0.41)	-0.13 (0.29)
Chemical	-3.15^{***} (0.65)	-2.23^{***} (0.43)
Logistics	-5.52^{***} (0.58)	-3.68^{***} (0.32)
Health-Care	-5.97^{***} (0.49)	-4.06^{***} (0.32)
Crisis	0.81^{***} (0.22)	0.63^{***} (0.17)
BIDDERS	0.65^{***} (0.04)	-
Constant	0.81^{***} (0.40)	-
Number of observation	15458	-
$\hat{\sigma}$	9.69	-
Pseudo R^2	32%	-
Likelihood Ratio (LR) χ^2 Test	139.48^{***}	-

Note: The limit for the corner solution is 0 and the number of observations at zero is 2428. Significance at the 10%, 5% and 1% levels are denoted respectively by *, **, ***.

Table 5 Tobit model for the average percentage decrease in procurement prices

However, as the coefficients corresponding to the inflation rate, days when the auction conducted, and currencies used in the auction have not been statistically significant we have ignored these control variables and presented the results obtained without them. To address a potential violation of the assumption of homoscedastic error terms, the robust standard errors are estimated for the coefficients. They are presented in parentheses next to the Tobit coefficients. Electrical works in the product categories, *Dutch* in the auction types, and the years in which there is no global financial crisis are treated as the base level for the Tobit model.

Because the coefficient of determination obtained for the Ordinary Least Squares estimators is misleading when the dependent variable is a corner solution response (Wooldridge 2002), we define the Pseudo R^2 which states the square of the correlation between the dependent variable and its estimate obtained by the Tobit model. Based on this pseudo R^2, that is 32% in the model, one can say that the Tobit conditional mean function fits the data moderately well. In addition, the p-value of the Likelihood Ratio test indicates that at least one of the Tobit coefficients is not equal to zero.

The partial effects of the auction types, the product categories, and the global financial crisis on %DECBID are estimated by *APE*. The estimated *APE* values are also given in Table 7.1. The

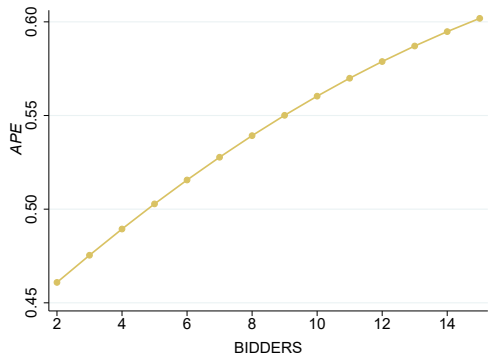


Figure 3 Average Partial Effects (APE) for the number of bidders

standard deviations of these estimations are obtained by using the bootstrapping method with 200 repetitions and they are presented in parentheses next to the corresponding *APE* values.

The *APE* values for the chemical, indirect material, and logistics product categories are negative and statistically significant at the 1% level. That is, e-auctions in these categories tend to yield a lower decrease in RFQBID compared to the ones in the electrical works category. In Table 7.1, the *APE* values also show that %DECBID significantly rises when e-auctions are implemented in the advertisement, manufacturing systems, and plastics product categories. According to the results, Hypothesis 1 is supported, that is, the product categories have an influence on the buyer surplus.

In Table 7.1, the Tobit coefficients indicate that the *Lot* and *Split* auctions exert positive and significant effects on %DECBID. This implies that the *Lot* and *Split* auctions led to a higher buyer surplus than the *Dutch* auctions. In the dataset, the auctioneer essentially implements the *English* auction rules while operating the *Lot* and *Split* auctions. The only difference between these two auction types stems from the award structure implemented at the end of auction. Since both *Lot* and *Split* auctions are superior to the *Dutch* auctions in terms of increasing the buyer surplus one can also conclude that the *English* auctions outperform the *Dutch* auctions. In addition, the *APE* value regarding the *Lot* auction means that %DECBID increases by 3% on average when the *Lot* auction is used. The *APE* value of the *Split* auction indicates that %DECBID increases on average by 1% with the use of the *Split* auction. Thus, one can conclude that the *Lot* auctions outperforms than the *Split* auctions in terms of decrease in procurement prices. On the basis of these results, we can conclude that Hypothesis 3 and Hypothesis 4 are supported. That is, the *Lot* auctions yield more buyer surplus compared to the *Split* auctions and the *English* auctions yield more buyer surplus compared to the *Dutch* auctions.

The Tobit coefficient regarding the crisis variable indicates that there is a positive association between %DECBID and the years in which the global financial crisis was observed. This association is also statistically significant at the 1% level. The corresponding *APE* value implies that %DECBID increased by 0.6% on average in the years that the effect of global financial crisis was observed. As

a result, we can conclude that Hypothesis 5 is supported, that is, the 2008 global financial crisis led to an increase in the buyer surplus. This effect is also investigated for the years 2010 and beyond by adding the dummy variables. However, the analysis shows that the effect of the economic crisis is not statistically significant after 2010.

The partial effects of the different numbers of bidders on %DECBID are estimated by APE and presented in Figure 3. The APE values for the different numbers of bidders are statistically significant at the 1% level. Figure 3 indicates that increasing the number of bidders leads to an increase in %DECBID. However, it is also observed that the positive marginal impact of the number of bidders on %DECBID is not constant and it gradually declines as the number of bidders increases. Specifically, an increase in the number of bidders from m to $m+1$ leads to a higher marginal benefit to buyer surplus, compared to an increase in the number of bidders from $m+1$ to $m+2$. As a result, Hypothesis 6 is supported, that is, the positive impact of having one more bidder in the auction on the buyer surplus decreases as the number of bidders is getting larger.

7.2. Classification of the product categories with respect to their impacts on the procurement prices

In this section, we classify the product categories based on their impacts on the average decrease in procurement prices. Additionally, we determine the %DECBID levels that roughly separate each group from the others.

Source	DF Num	DF Den	F-Value	p-value
Prdouct Category	13	1409.5	247.2	0.00

Table 6 Welch's ANOVA Test

We primarily investigate whether the average percentage decrease in at least one product category is different than the ones in the others. For this investigation, we use Welch's ANOVA test and present the corresponding results in Table 7.2. The p-value regarding the test is smaller than 0.05 which implies that at least one product category has a different average percentage decrease in the procurement prices compared to the others.

For the Welch's ANOVA test, the results indicate that not all product category means are equal. However, these results do not tell us precisely which product category means are different and which of the product categories can be considered in the same group. To identify statistically significant differences between specific product categories and to group the product categories in a correct manner, we need to perform a pairwise comparisons post-hoc test. To address this issue, we employed the Games-Howell Pairwise Comparisons tests. The results regarding the classification of the product categories are given in Table 7.2. For the sake of brevity, the results regarding the pairwise mean comparisons across product categories are given in Appendix.

Product Category	N	Average %DECBID	Grouping				
Advertisment	281	13.3	A				
Plastics	72	12.9	A				
Manufacturing Sys.	116	11.5	A	B			
Service	699	10.5	A	B			
Textile	388	9.6		B			
Direct Material	4350	9.4		B			
In-Direct Material	2449	8.9		B			
Construction	3457	8.9		B	C		
Technological Eq.	400	8.6		B	C		
Metal	421	8.6		B	C		
Electrical Works	584	7.5			C		
Logistics	339	4.9				D	
Chemical	162	4.2				D	E
Health-Care	1740	3.3					E

Note: Product categories that do not share a letter are significantly different.

Table 7 Games-Howell Pairwise Comparisons Test Results

The results regarding the Games-Howell tests indicate that for the advertisement, plastics, manufacturing systems, and service categories, there is no statistical difference on the average decrease in procurement prices. That is, these product categories can be considered in the same group. As the advertisement, plastics, manufacturing systems, and service categories have higher averages compared to others we name the group containing these categories as *High*. The Games-Howell tests results imply that textile, direct material, indirect material, construction, technological equipments, metal, and electrical works categories can constitute a group. The group including these categories is called as *Medium*. From the Games-Howell tests results, it is also observed that the logistics, chemical, and health-care categories can form a group. Since the averages percentage decreases in the procurement prices are smaller for logistics, chemical, and health-care categories than for the others, the group covering these categories is named as *Low*. The results of the classification of the product categories are summarized in Table 7.2.

With these efforts, we also confirm that Hypothesis 2 is supported, that is, the product categories can be grouped based on their impacts on the average decrease in procurement prices.

High	*Medium*		*Low*
- Advertisement	- Construction	- Metal	- Chemical
- Manufacturing Sys.	- Direct Material	- Textile	- Health-Care
- Plastics	- Electrical Works	- Technological Eq.	- Logistics
- Service	- In-Direct Material		

Table 8 Classification of the product categories based on the average decrease in procurement prices

Additionally, we specify the %DECBID levels that roughly separate each group from the others. For specifying the separation levels, we use the highest average %DECBID and the lowest average %DECBID in the *Medium* group, which are 9.6% and 7%, respectively. To observe whether the

levels are appropriate for classifying the product categories, we construct a 95% lower one-sided confidence interval on the mean of %DECBID for each product category and present them in Figure 4.

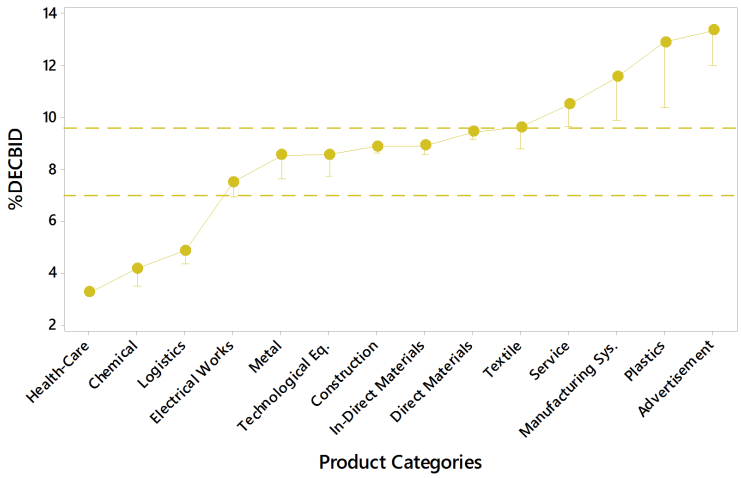


Figure 4 95% lower one-sided confidence intervals on the averages of %DECBID by the product categories

Figure 4 indicates that the separation levels, 9.6% and 7%, moderately well work for classifying the product categories into three major groups. With these levels, we can provide an additional information on the groups. For the product categories in the *Low* group, the average percentage decrease in procurement prices is lower than 7%. Additionally, the average percentage decrease in procurement prices is between 7% and 9.6% for the product categories in the *Low* group whereas the average percentage decrease in procurement prices is higher than 9.6% for the product categories in the *High* group.

To statistically confirm the observations acquired from the figure, we also perform the student's t-test at the significance level of 0.05. We test the hypotheses that for the chemical, health-care, and logistics categories, the average %DECBID is smaller than 7%. As all of the obtained p-values are lower than 5%, we reject the null hypotheses. That is, there is sufficient evidence at the 0.05 level of significance to conclude the average %DECBID is smaller than 7% for the chemical, health-care, and logistics categories. We investigate the hypotheses that the %DECBID means in the construction, direct material, electrical works, indirect material, metal, technological equipments, and textile categories are smaller than 9.6%, but higher than 7%. The p-values obtained from student's t-tests imply that the considered hypotheses are supported. As a result, we can conclude that for the *Medium* group, the average %DECBID is between 9.6% and 7%. We also assess the hypotheses that for the advertisement, manufacturing systems, service, and plastics categories, the average %DECBID is greater than 9.6%. The obtained p-values support the hypotheses at the significance

level of 0.05. So, we conclude that the average %DECBID is greater than 9.6% for the product categories in the *High* group. With these efforts, we give an idea about the %DECBID levels that roughly separate each group and identify the product categories that can provide high benefits for the buyers when the e-auction implementations are used.

7.3. Analysis of the effect of the group buying on the procurement prices

In the dataset, we observe two buyer types: (1) the individual buyers that make purchases on their own and (2) the GPO that is an entity authorized to act as a purchasing agent for a group of individual buyers. In this section, it is investigated whether there is a difference between these two buyer types with respect to the average percentage decrease in RFQBID. The result of this investigation allows us to understand the effect of group purchasing programs on the average percentage decrease in procurement prices.

	GPO			Individual Buyers			
Variable	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**Differences in Means**
%DECBID	1662	9.24	8.97	13796	8.32	8.95	$\mu_{GPO}^{\%DECBID} > \mu_{Individual}^{\%DECBID***}$
BIDDERS	1662	6.63	4.12	13796	4.81	2.93	$\mu_{GPO}^{BIDDERS} > \mu_{Individual}^{BIDDERS***}$

Note: Significance at the 10%, 5% and 1% levels are denoted respectively by *, **, ***.

Table 9 **Comparisons of the buyer types with respect to the average percentage decrease in the procurement prices and the average number of bidders**

The hypothesis that the average percentage decrease in RFQBID is higher for the GPO than for the individual buyers, $\mu_{GPO}^{\%DECBID} - \mu_{Individual}^{\%DECBID} > 0$, is considered while conducting the statistical test. The results are presented in Table 7.3. As a result of the test, the null hypothesis is rejected at the 1% significance level. Thus, we conclude that the average purchasing prices achieved with the group purchasing options is lower than the one achieved with the individual buying option. This implies that Hypothesis 7 is supported.

By considering the hypothesis that the average number of bidders that participate in the auctions executed for the GPO is higher than the average number of bidders that participate in the auctions executed for the individual buyers, $\mu_{GPO}^{BIDDERS} - \mu_{Individual}^{BIDDERS} > 0$, we also compare the GPO and the individual buyers with respect to the average number of bidders. Two sample student t-test with unequal variances assumption is employed for the statistical comparison. The results are presented in Table 7.3. At the 1% significance level, the null hypothesis is rejected. Thus, we draw the conclusion that the average number of bidders that participate in auctions executed for the GPO is higher than that for the individual buyers. With this effort, we conclude that the group purchasing programs achieve more decrease in the procurement prices compared to the individual buyers. One of the possible reasons behind this result is the fact that more suppliers participate in the auctions executed for the group purchasing option compared to the ones for the individual

buying option. Additionally, since the GPO combines the demands of a group of individual buyers in the auctions, there could be a positive impact of the economies of scale on the findings related to %DECBID and BIDDERS.

7.4. Analysis of the effect of the contract types on the procurement prices

In this section, we examine the effects of *Percentage* and *Fixed* contract types on the average decrease in procurement prices by using two sample student t-test with unequal variances assumption. The hypothesis that the *Fixed* contract type yields a higher average decrease in procurement prices compared to the *Percentage* contract type, $\mu_{Fixed}^{\%DECBID} - \mu_{Percentage}^{\%DECBID} > 0$, is considered while conducting the statistical test. The results are presented in Table 7.4.

	***Percentage* Contract**			***Fixed* Contract**			
Variable	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**Differences in Means**
%DECBID	12004	8.58	8.98	359	8.86	8.95	$\mu_{Fixed}^{\%DECBID} = \mu_{Percentage}^{\%DECBID}$

Note: Significance at the 10%, 5% and 1% levels are denoted respectively by *, **, ***.

Table 10 Comparisons of Percentage and Fixed contract types with respect to the average percentage decrease in the procurement prices

As a result of the test, at the 1% significance level, the null hypothesis cannot be rejected. So, there is no statistical evidence to conclude that the *Fixed* contract yields a higher average decrease in procurement prices compared to the *Percentage* contract. One of the possible reasons behind this result is that the auctioneer reasonably determines the values of the contract parameters in the *Fixed* and *Percentage* contract types. Thus, both of the contract types yield the same efficiency in terms of the decrease in procurement prices. In addition, the buyers generally attach importance to the offers submitted in the RFQ process and attempt to decrease it as much as they can without considering the contract type. As a result, there is no difference between the *Fixed* and *Percentage* contract types with respect to the average decrease in procurement prices. Consequently, we cannot support Hypothesis 8 that the *Fixed* contract yields a higher average decrease in procurement prices compared to the *Percentage* contract type.

A comparison between the *Mixed* and the other contract types is not considered in this section. Since the customer specific contract parameters in the *Mixed* contract are not observed in the dataset, we cannot compare the *Mixed* contracts and the other two contract types, accurately. Because, in the *Mixed* contract, the contract parameters can be specified in a way that the fixed fee is significantly higher than the amount of share. In such a case, the effect of using *Mixed* contract on the decrease in procurement prices would be similar to that of the *Fixed* contract. On the other hand, for the case of *Mixed* contract, the amount of share can be set to a higher level compared to the fixed fee. Under this setting, the effects of using the *Mixed* contract on the decrease in

procurement prices would be similar to that of the *Percentage* contract. This fact leads to the higher variance in the decrease in procurement prices achieved with the use of the *Mixed* contract type. Hence, the comparison between the *Mixed* and the other contract types would not be consistent and unbiased.

7.5. Analysis of the effect of the e-auction platform ownership on the procurement prices

In June 2013, the e-auction platform was acquired by one of the platform's corporate users. The new owner of the platform is a member of a large industrial group that has 113 companies located across 22 countries with 26 billion USD total consolidated revenue. The new owner represents and makes use of a notable buying power on behalf of its group. By using the economies of scale that the group has, it began to offer the group purchasing events for the members of its own group and other corporate customers.

In the dataset, all the procurement events conducted for the new owner of the platform, including before and after the acquisition, were managed with the *Percentage* contracts. Additionally, most of the procurement events were run by implementing the *Lot* auction rules. In the analysis, to avoid the effects of the other factors except for the ownership change, we eliminate the data points that include the *Split* and *Dutch* auctions. As a result of this effort, we obtain a dataset that covers the online purchasing events organized for the new owner of the platform and that does not include any additional policy, structural or contract changes. So, the dataset we prepared for this analysis includes a natural experiment that allows investigating the effect of the ownership of the e-auction platform on the buyer surplus.

	After the Acquisition			**Before the Acquisition**			
Variable	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**Differences in Means**
%DECBID	962	10.45	9.78	700	7.58	7.41	$\mu_{Before}^{\%DECBID} = \mu_{After}^{\%DECBID}$

Note: Significance at the 10%, 5% and 1% levels are denoted respectively by *, **, ***.

Table 11 **Comparisons of the averages of percentage decrease in procurement prices obtained before and after the date the e-auction platform is acquired by the purchasing organization**

To exploit this natural experiment, we test the hypothesis that the average decrease in procurement prices obtained before the acquisition of the e-auction platform is higher than the average decrease in procurement prices obtained after the acquisition, $\mu_{Before}^{\%DECBID} - \mu_{After}^{\%DECBID} > 0$. Two sample student t-test with unequal variances assumption is employed for conducting the hypothesis test and the results are presented in Table 7.5. As a result of the test, at the 1% significance level, the null hypothesis cannot be rejected. So, there is no statistical evidence to conclude that the average decrease in procurement prices achieved before the acquisition is higher than the average decrease

in procurement prices achieved after the acquisition. This result implies that the Hypothesis 9 is not supported.

One of the possible reasons behind this result is that the suppliers' perceptions of opportunism could decrease after the acquisition as the new owner of the platform possibly conduct high volume auctions due to its operations scope. This result is coherent with the findings in the work of Jap (2007). Another reason underlying behind this result could be the fact that the new owner of the auction platform still continues to provide auction solutions to the ones out of its group. This fact may not change the suppliers' perceptions to the owner of the auction platform and the suppliers can perceive the owner as the one operating the platform independently rather than the one operating the platform for its group and the other corporate customers. On the other hand, this reason also is coherent with the findings in the work of Wyld (2011).

8. Summary of Findings

In this section, we summarize the main findings derived from the empirical analysis and the possible factors that drive these findings. Table 8 shows the summary of our hypothesis test results.

Hypothesis 1. The product categories have a notable influence on the buyer surplus.	Supported
Hypothesis 2. The product categories can be grouped based on their impacts on the average decrease in procurement prices.	Supported
Hypothesis 3. *English* auctions yield more buyer surplus compared to *Dutch* auctions.	Supported
Hypothesis 4. *Lot* auctions yield more buyer surplus compared to *Split* auctions.	Supported
Hypothesis 5. The 2008 global financial crisis led to an increase in the buyer surplus.	Supported
Hypothesis 6. The positive impact of having one more bidder in the auction on the buyer surplus decreases as the number of bidders is getting larger.	Supported
Hypothesis 7. The average purchasing prices achieved with group purchasing options is lower than the one achieved with the individual buying option.	Supported
Hypothesis 8. *Percentage* contract type yields a lower average decrease in procurement prices compared to *Fixed* contract type.	Not Supported
Hypothesis 9. The average decrease in procurement prices is higher for the auctions conducted through the third-party auction provider than for the auctions conducted through the private auction platform.	Not Supported

Table 12 Results of statistical hypothesis tests

8.1. Summary of findings regarding the buyer surplus

The empirical results indicate that product categories have a notable effect on the buyer surplus. The decrease in procurement prices significantly increases when the e-auction is executed in one of the categories of advertisement, manufacturing systems, service, and plastics. We attribute this result to the fact that the products in the categories of advertisement, service, and manufacturing

systems are experience goods, thus bidders mostly intend to increase the initial offers submitted before the e-auction starts. However, it is observed that the buyer surplus decreases when the e-auction is conducted in the chemical, logistics, and health-care categories. The cost structures of products in the chemical and logistics categories directly depend on the commodity markets, thus, the decrease in procurement prices that can be achieved at the end of the auction is limited. The buyers in the health-care category use e-auctions to easily document their transactions rather than to increase their surpluses. This particular use of e-auctions explains why the e-auctions conducted in this category yield a lower decrease in procurement prices compared to the other categories. The majority of the existing literature has proposed that the use of the reverse auction is advantageous in the purchase of commodity items, especially where the price is the primary consideration. However, in this study, we ascertain that this online procurement tool is not only a valuable tool for the purchase of commodity items, but also could be of value for purchasing more complex items. The results we obtain here imply that there is an opportunity of achieving a large decrease in the procurement prices for the complex products which are in the advertisement, service, and manufacturing systems categories by using e-auctions.

We show that *English* auctions yield more buyer surplus compared to *Dutch* auctions whereas *Lot* auctions yield a greater increase in the buyer surplus compared to *Split* auctions. The superiority of the *English* auction over the *Dutch* auction can be related to the auction dynamics. In the *English* auctions, the bidders compete with each other by submitting consecutively bids. This structure creates an iterative process that continues until a price is reached where there is just a single bidder who is willing to supply the auctioning item. However, in *Dutch* auctions, the price is monotonically increased by the auctioneer until there is a single bidder who is willing to supply at the currently announced price. The bidding rules difference causes the fact that the competition among the suppliers is less in the *Dutch* auctions compared to the *English* auctions. As a natural result of this fact, we observe that *Dutch* auction's efficiency is worse than *English* auction's efficiency. The results regarding the comparison of the *English* and *Dutch* auctions efficiencies' seem coherent with the forward auction literature. However, we are not aware of any studies that deal with the comparison of the impacts of *English* and *Dutch* auction types on the buyer surplus by considering the reverse auction setting. Therefore, we believe that with this analysis, our work contributes to the literature by extending the corresponding result to the context of reverse auctions. Additionally, the superiority of the *Lot* auction over the *Split* auction can be attributed to the economies of scale. Because in the *Lot* auction type, the winner supplies all the auctioning items whereas in the *Split* auction type, the auctioning items can be supplied by multiple suppliers. Since the *Lot* auctions generally offer the high-volume transactions due to its award-structure the bidders participating in the *Lot* auction type could be more willing to be a winner compared to the ones participating in

the *Dutch* auction type. This fact intensifies the competition in the *Lot* auctions thereby increasing its efficiency. The results that we derived for the comparison of the impacts of the *Lot* and *Split* auction types are in the same line with the literature. The existing studies focus on this subject by conducting surveys and/or laboratory experiments. By conducting an econometric analysis on a real dataset, we reveal that the practitioners' intuitions that have been observed in the surveys are coherent with the results that have been obtained in practice. So, this can be considered as another contribution of the study to the literature.

We conclude that the 2008 global financial crisis led to an increase in the buyer surplus. The economic downturn periods typically leads a reduction in the market demand, because, most of the companies dramatically cut their spendings to bear the possible financial and/or operational risks. This effect could force the suppliers to lower their prices in order to sell off the excess capacities emerged due to crimping demand. As a result of a downturn in the market, the competition among the suppliers participating in the auctions would intensify so that the auction prices would go down. To the best of our knowledge, this is the first attempt to focus on the analysis of the financial crisis on the buyer surplus obtained with the use of the e-auctions. So, another contribution of this study is the understanding of how this factor affects the buyer surplus. Unlike the existing studies, we observe that the positive impact of having one more bidder in the auction on the buyer surplus decreases as the number of bidders is getting larger. This result can be attributed to the fact that the competition in the auction does not further increase after a certain number of suppliers participates in the event. The results regarding this factor also indicate that most of the positive effect of this factor can be achieved by inviting 5 to 10 suppliers to the auction.

As a result of the analysis on the effect of the product categories on the buyer surplus, we classified the product categories into three groups according to the average percentage decrease in the procurement prices and determine the %DECBID levels that roughly separate each group from the others. The chemical, health-care, and logistics categories are grouped as the group that yields *Low* decrease in procurement prices. The average decrease in procurement prices for the auctions in this group is smaller than 7%. The construction, direct material, electrical works, indirect material, metal, technological equipments, and textile categories are grouped as the group that yields *Medium* decrease in procurement prices. The average decrease in procurement prices for the auctions in this group is between 7% and 9.6%. The advertisement, manufacturing systems, service, and plastics categories are grouped as the group that yields *High* decrease in procurement prices. The average decrease in procurement prices for the auctions in this group is greater than 9.6%. With this effort, we give an idea about the %DECBID levels that roughly separate each group and specify the product categories that can provide high benefits for the buyers when the e-auction implementations are used.

8.2. Summary of findings regarding the purchasing price

The statistical analyses imply that the average purchasing prices achieved with the group purchasing options is lower than the one achieved with the individual buying option. One of the possible reasons behind this result is that the number of bidders participating in the auctions conducted for the group purchasing programs is higher than the number of bidders participating in the auctions conducted for the individual buyers. The economies of scale that are created with the group purchasing events could also be effective on the results obtained for the average decrease in procurement prices and the number of bidders. Additionally, we conclude that there is no statistical difference between the contract types of *Fixed*, in which a fixed fee is charged for executing the e-auction, and *Percentage*, in which a share is charged from the generated value due to the e-auction. This result may be attributed to the fact that the auctioneer reasonably determines the values of the contract parameters in *Fixed* and *Percentage* contracts. Another reason can be the fact that, without considering the contract type, the buyers give importance to the process in which the offers are submitted before the e-auction starts. We also find that there is no statistical evidence to conclude that the average decrease in auctions prices are higher for those who use the third-party's platform than for those who use their own platform. This result implies that the suppliers' perceptions to the auctioneer have not changed after one of the platform's corporate users acquired the auction platform. That is, the suppliers have continued to believe in the new service provider's neutrality and legitimacy. This can be ascribed to the fact that the suppliers' concerns about opportunism decrease since the service provider likely manages the auctions being large transaction volumes because of its operations scope. Another reason could be the fact that the new provider has still continued to provide auction solutions to the other corporate buyers rather than using the platform for only its own purchasing events. Another contribution of this study is to incorporate the analysis regarding the effects of the group purchasing, contract type, and auction platform ownership on the buyer surplus into the reverse auction literature.

9. Conclusions and Further Developments

In this paper, we empirically examine online procurement auctions managed by a third-party auction provider between March 2006 and March 2016. The dataset includes the transaction details of 15458 e-auction events executed in 14 different product categories using three different auction formats. In the dataset, there are two types of buyers: the individual buyers that directly use the e-auction platform and the group purchasing organization that operates as a purchasing agent for a group of individual buyers.

The main contribution of this study is analyzing the buyer surplus, attempting a number of factors that have not been addressed in the literature. In this context, the joint impacts of the

product category, the auction type, the 2008 global financial crisis, and the number of participating bidders on the buyer surplus obtained from e-auctions are examined empirically. Based on the results obtained from the empirical analysis, we observe that the product category, the auction format, and the 2008 financial crisis have a notable effect on the buyer surplus. Additionally, we find the positive marginal impact of the number of bidders to the buyer surplus is not constant and the positive impact decreases as the number of bidders increases. Such a result regarding the number of bidders has not ever been emphasized in the literature. Accordingly, we believe that our work also contributes to the literature by establishing the result that a positive impact of having one more supplier in the auction to the buyer surplus decreases when the number of bidders is getting larger. This study also indicates that the product categories can be classified into three different groups according to their impacts on the average decrease in procurement prices. It contributes to the literature by showing the fact that on the average, the option of group purchasing achieves a higher decrease in procurement prices compared to the option of individual buying. The influences that the contract types have on the average decrease in procurement price are also examined and no statistically significant difference is observed among the contract types. The analysis indicates that there is no statistical difference between the average price reduction achieved through the use of the third-party's platform and the one achieved through the use of the private auction platform. The main findings derived in the study are given in Section 7.

An interesting topic for future research would be a study that deals with the effects of the incumbency, the supplier service quality, the contract duration, and the visual design parameters on the buyer surplus. Further investigations of what drives the suppliers' behaviors in the auction and which factors yield a benefit for the suppliers are needed. Investigating the possible effects of buyer-specific characteristics such as market share, capacity, and size on the surplus and examining the interactions between these characteristics and suppliers' behaviors could also be interesting extensions for the current work. Due to the lack of sufficient data, we have not addressed these factors in the analysis. Since we do not have the firm-specific and the product-specific information sets, we could not employ a standard classification of categories by following portfolio management models, e.g., the Kraljic Matrix. Considering such a classification scheme would be a valuable extension for the study and make a considerable contribution to having univocal results. It is also important for the practitioners to identify the source of price reduction achieved through the reverse auctions. Therefore, another topic would be to look at the question that is, how sustainable are the price reductions. In the study, as there is no sufficient information in the dataset to derive the main factors that drive the results regarding the group purchasing, the contract type, and the platform ownership, they are also left for future studies.

We believe that the insights driven here will be of value to the firms planning to incorporate e-auctions into the procurement processes since they provide a guideline on how to achieve a higher surplus by specifying the product category and auction type. As the majority of the factors that we deal with in this study have not been addressed in the literature, we strongly regard that this work provides researchers to the new understanding of how and what factors affect the buyer surplus within the reverse auction context. In addition, this study can be valuable for the firms that intend to use a purchasing agent to execute their procurement events because it shows that a group purchasing organization can achieve a higher surplus compared to the individual buyers.

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Appendix

Difference of Levels	Difference of Means	Standard Error of Difference	%95-Confidence Interval	t-value	Adjusted p-value
Logistics - Chemical	0.70	0.46	(-0.91; 2.30)	1.53	0.96
Health-Care - Chemical	-0.91	0.36	(-2.21; 0.39)	-2.50	0.41
Electrical Works - Chemical	3.33	0.46	(1.72; 4.94)	7.28	0.00
In-Direct Material - Chemical	4.73	0.40	(3.33; 6.13)	11.91	0.00
Construction - Chemical	4.70	0.38	(3.34; 6.06)	12.31	0.00
Metal - Chemical	4.37	0.60	(2.27; 6.48)	7.30	0.00
Technological Eq. - Chemical	4.39	0.56	(2.41; 6.37)	7.78	0.00
Textile - Chemical	5.44	0.57	(3.45; 7.43)	9.62	0.00
Direct Material - Chemical	5.27	0.39	(3.89; 6.65)	13.54	0.00
Service - Chemical	6.31	0.57	(4.30; 8.32)	11.03	0.00
Manufacturing Sys. - Chemical	7.38	0.93	(4.04; 10.71)	7.92	0.00
Plastics - Chemical	8.73	1.37	(3.73; 13.72)	6.35	0.00
Advertisement - Chemical	9.17	0.78	(6.41; 11.93)	11.69	0.00
Health-Care - Logistics	-1.60	0.29	(-2.63; -0.58)	-5.49	0.00
Electrical Works - Logistics	2.64	0.40	(1.21; 4.05)	6.53	0.00
In-Direct Material - Logistics	4.03	0.33	(2.86; 5.21)	12.10	0.00
Construction - Logistics	4.01	0.32	(2.90; 5.12)	12.71	0.00
Metal - Logistics	3.68	0.56	(1.71; 5.64)	6.58	0.00
Technological Eq. - Logistics	3.70	0.52	(1.86; 5.53)	7.09	0.00
Textile - Logistics	4.74	0.52	(2.91; 6.58)	9.08	0.00
Direct Material - Logistics	4.57	0.32	(3.44; 5.71)	14.13	0.00
Service - Logistics	5.62	0.53	(3.75; 7.48)	10.60	0.00
Manufacturing Sys. - Logistics	6.68	0.91	(3.43; 9.93)	7.37	0.00
Plastics - Logistics	8.03	1.36	(3.09; 12.97)	5.92	0.00
Advertisement - Logistics	8.47	0.75	(5.82; 11.12)	11.24	0.00
Electrical Works - Health-Care	4.24	0.30	(3.21; 5.28)	14.39	0.00
In-Direct Material - Health-Care	5.64	0.19	(4.98; 6.30)	30.07	0.00
Construction - Health-Care	5.61	0.15	(5.08; 6.15)	36.68	0.00
Metal - Health-Care	5.28	0.49	(3.58; 6.99)	10.87	0.00
Technological Eq. - Health-Care	5.30	0.44	(3.75; 6.86)	11.98	0.00
Textile - Health-Care	6.35	0.44	(4.79; 7.91)	14.31	0.00
Direct Material - Health-Care	6.18	0.17	(5.58; 6.78)	36.41	0.00
Service - Health-Care	7.22	0.45	(5.63; 8.81)	15.96	0.00
Manufacturing Sys. - Health-Care	8.29	0.86	(5.18; 11.40)	9.60	0.00
Plastics - Health-Care	9.64	1.33	(4.78; 14.50)	7.25	0.00
Advertisement - Health-Care	10.10	0.70	(7.61; 12.55)	14.37	0.00
In-Direct Material - Electrical Works	1.40	0.34	(0.22; 2.58)	4.17	0.00
Construction - Electrical Works	1.37	0.32	(0.26; 2.49)	4.33	0.00
Metal - Electrical Works	1.04	0.56	(-0.92; 3.01)	1.86	0.85
Technological Eq. - Electrical Works	1.06	0.52	(-0.78; 2.90)	2.03	0.75
Textile - Electrical Works	2.11	0.52	(0.27; 3.95)	4.03	0.00
Direct Material - Electrical Works	1.94	0.33	(0.80; 3.08)	5.96	0.00
Service - Electrical Works	2.98	0.53	(1.11; 4.85)	5.61	0.00

Table 13 Games-Howell Simultaneous Tests for Difference of Means

Difference of Levels	Difference of Means	Standard Error of Difference	%95-Confidence Interval	t-value	Adjusted p-value
Manufacturing Sys. - Electrical Works	4.05	0.91	(0.79; 7.30)	4.46	0.00
Plastics - Electrical Works	5.40	1.36	(0.45; 10.34)	3.97	0.01
Advertisement - Electrical Works	5.84	0.76	(3.19; 8.49)	7.74	0.00
Construction - In-Direct Material	-0.03	0.22	(-0.80; 0.75)	-0.12	1.00
Metal - In-Direct Material	-0.36	0.51	(-2.15; 1.44)	-0.70	1.00
Technological Eq. - In-Direct Material	-0.34	0.47	(-1.99; 1.31)	-0.72	1.00
Textile - In-Direct Material	0.71	0.47	(-0.94; 2.37)	1.50	0.97
Direct Material - In-Direct Material	0.54	0.23	(-0.28; 1.36)	2.32	0.54
Service - In-Direct Material	1.58	0.48	(-0.11; 3.27)	3.30	0.06
Manufacturing Sys. - In-Direct Material	2.65	0.88	(-0.51; 5.80)	3.01	0.15
Plastics - In-Direct Material	4.00	1.34	(-0.89; 8.88)	2.98	0.17
Advertisement - In-Direct Material	4.44	0.72	(1.91; 6.97)	6.17	0.00
Metal - Construction	-0.33	0.50	(-2.09; 1.43)	-0.66	1.00
Technological Eq. - Construction	-0.31	0.46	(-1.92; 1.30)	-0.68	1.00
Textile - Construction	0.74	0.46	(-0.88; 2.35)	1.60	0.95
Direct Material - Construction	0.57	0.21	(-0.16; 1.29)	2.74	0.25
Service - Construction	1.61	0.47	(-0.04; 3.25)	3.44	0.04
Manufacturing Sys. - Construction	2.67	0.87	(-0.46; 5.80)	3.07	0.13
Plastics - Construction	4.02	1.33	(-0.85; 8.89)	3.01	0.16
Advertisement - Construction	4.47	0.71	(1.97; 6.97)	6.28	0.00
Technological Eq. - Metal	0.02	0.65	(-2.27; 2.30)	0.03	1.00
Textile - Metal	1.07	0.65	(-1.22; 3.35)	1.64	0.94
Direct Material - Metal	0.90	0.50	(-0.88; 2.67)	1.77	0.89
Service - Metal	1.94	0.66	(-0.37; 4.25)	2.95	0.16
Manufacturing Sys. - Metal	3.00	0.99	(-0.51; 6.52)	3.05	0.13
Plastics - Metal	4.35	1.41	(-0.76; 9.46)	3.08	0.13
Advertisement - Metal	4.80	0.85	(1.82; 7.78)	5.66	0.00
Textile - Technological Eq.	1.05	0.62	(-1.13; 3.22)	1.69	0.92
Direct Material - Technological Eq.	0.88	0.46	(-0.75; 2.51)	1.90	0.83
Service - Technological Eq.	1.92	0.63	(-0.28; 4.12)	3.07	0.11
Manufacturing Sys. - Technological Eq.	2.99	0.97	(-0.46; 6.43)	3.09	0.12
Plastics - Technological Eq.	4.34	1.40	(-0.73; 9.40)	3.10	0.13
Advertisement - Technological Eq.	4.78	0.82	(1.88; 7.67)	5.80	0.00
Direct Material - Textile	-0.17	0.47	(-1.80; 1.47)	-0.36	1.00
Service - Textile	0.87	0.63	(-1.33; 3.07)	1.39	0.98
Manufacturing Sys. - Textile	1.94	0.97	(-1.51; 5.38)	2.01	0.76
Plastics - Textile	3.29	1.40	(-1.78; 8.36)	2.35	0.52
Advertisement - Textile	3.73	0.82	(0.83; 6.63)	4.52	0.00
Service - Direct Material	1.04	0.47	(-0.62; 2.70)	2.20	0.63
Manufacturing Sys. - Direct Material	2.11	0.88	(-1.04; 5.25)	2.41	0.48
Plastics - Direct Material	3.46	1.34	(-1.42; 8.33)	2.59	0.37
Advertisement - Direct Material	3.90	0.72	(1.39; 6.41)	5.45	0.00
Manufacturing Sys. - Service	1.07	0.97	(-2.39; 4.52)	1.10	1.00
Plastics - Service	2.41	1.40	(-2.67; 7.50)	1.72	0.90
Advertisement - Service	2.86	0.83	(-0.06; 5.77)	3.45	0.04
Plastics - Manufacturing Sys.	1.35	1.58	(-4.33; 7.03)	0.85	1.00
Advertisement - Manufacturing Sys.	1.79	1.11	(-2.10; 5.69)	1.62	0.94
Advertisement - Plastics	0.44	1.50	(-4.96; 5.84)	0.30	1.00

Table 13 (Cont'd) Games-Howell Simultaneous Tests for Difference of Means

Product Category	Corresponding UNSPC Segment Codes and Segment Names
Direct Material	24000000 - Material Handling and Conditioning and Storage Machinery and Accessories and Supplies 27000000 - Tools and General Machinery 31000000 - Manufacturing Components and Supplies
Construction	22000000 - Building and Construction Machinery and Accessories 72000000 - Building and Facility Construction and Maintenance Services Supplies
In-Direct Material	14000000 - Paper Materials and Products 44000000 - Office Equipment and Accessories and Supplies 48000000 - Service Industry Machinery and Equipment and Supplies 56000000 - Furniture and Furnishings
Health-Care	42000000 - Medical Equipment and Accessories and Supplies 51000000 - Drugs and Pharmaceutical Products 85000000 - Healthcare Services
Service	76000000 - Industrial Cleaning Services 77000000 - Environmental Services 80000000 - Management and Business Professionals and Administrative Services 84000000 - Financial and Insurance Services 86000000 - Education and Training Services 90000000 - Travel and Food and Lodging and Entertainment Services
Electrical Works	26000000 - Power Generation and Distribution Machinery and Accessories 39000000 - Electrical Systems and Lighting and Components and Accessories and Supplies
Metal	11000000 - Mineral and Textile and Inedible Plant and Animal Materials
Technological Eq.	32000000 - Electronic Components and Supplies 43000000 - Information Technology Broadcasting and Telecommunications 45000000 - Printing and Photographic and Audio and Visual Equipment and Supplies
Textile	53000000 - Apparel and Luggage and Personal Care Products
Logistics	78000000 - Transportation and Storage and Mail Services
Advertisement	82000000 - Editorial and Design and Graphic and Fine Art Services
Chemical	12000000 - Chemicals including Bio-Chemicals and Gas Materials 15000000 - Fuels and Fuel Additives and Lubricants and Anti-corrosive Materials
Manufacturing Sys.	73000000 - Industrial Production and Manufacturing Services 81000000 - Engineering and Research and Technology Based Services
Plastics	13000000 - Resin and Rosin and Rubber and Foam and Film and Elastomeric Materials

Table 14 **The product categories considered in this study and the corresponding UNSPC segments**