

Selling Order Matters in Sequential Auctions: Experimental
Evidence

by

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Abstract

We study how the order in which two heterogeneous products are sold in a second-price sequential auction affects efficiency, revenue, and, notably, the probability of ex-post loss for bidders. Theoretically, when the lower variance product is sold first, rather than second, the probability of ex-post loss for the global bidder increases. This leads to higher revenue at the expense of bidders, while reducing efficiency. Our experimental results confirm this theoretical prediction, showing that the probability of ex-post loss is indeed higher when the lower variance product is sold first, and that efficiency increases under this ordering when synergy is low. This risk of ex-post loss is important because if firms go bankrupt due to overbidding, they may fail to complete critical public projects such as highways or hospitals, causing delays that prevent the public from accessing essential services. Our study shows the correct selling order to mitigate this problem, offering insights that can help shape public policy to minimize bidder losses and improve project completion outcomes.

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Chapter 1

Introduction

Sequential auctions occur in a variety of contexts, such as land sales, license auctions, fisheries rights, military procurement, and highway construction projects (e.g., [Krishna and Rosenthal, 1996](#); [Reiß and Schöndube, 2002](#); [De Silva, 2005](#); [Kong, 2021](#)). For example, governments frequently use sequential auctions for highway construction projects. When a company wins the contract for the first segment of a highway, it becomes more motivated to win the contract for the second segment due to two main factors: operational efficiency and revenue synergies. The first arises from already having the necessary equipment and teams in place, while the second comes from the ability to optimize tolls and improve traffic flow by controlling multiple segments. In such sequential auctions, bidders are often classified as global or local. Global bidders compete for two products in different local markets and may derive synergies if they win both, whereas local bidders focus on securing a single product in their respective local markets. However, as in the highway example, a company may still go bankrupt after winning both contracts due to overbidding, even if it captures the synergy and generates revenue.

This bankruptcy risk is particularly concerning because if firms fail financially after winning contracts, important public infrastructure projects, such as highways

or hospitals, may remain unfinished or face significant delays. As a result, the public may be deprived of critical services and economic benefits that these projects are intended to deliver.

In this study, we experimentally test the theoretical results of [Gunay et al. \(2024\)](#), who examine how the order in which two heterogeneous products are sold influences auction outcomes, specifically in terms of efficiency, revenue, and negative payoffs for the bidders. In their model, product heterogeneity is represented by variance in valuations, with one product having almost zero variance. In their perfect Bayesian equilibrium, local bidders bid their true valuations in both auctions. The global bidder, however, bids above its standalone value for the first product, which can result in negative payoffs if it fails to win the second product or wins it with insufficient profit to offset the loss. For the second product, the global bidder bids truthfully. They show that selling the product with almost zero variance first leads to higher revenue, lower efficiency, and more negative payoffs (i.e., a loss for the global bidder).

We build an experimental setting based on the theoretical model of [Gunay et al. \(2024\)](#). In our experiment, we vary the selling order of product (Order AB vs. Order BA) and the level of synergy (high vs. low) in second-price sequential auctions across sessions, ensuring that no player participates in more than one session. The experiment consists of two parts. The first part is a 23-period second-price sequential auction, where two heterogeneous products, Product A and Product B, are auctioned in each period. Product B has a lower variance in its valuation than Product A. In each auction, there is one global bidder (the player) and two local bidders (the computers). The valuations of the products are private information, but all bidders know Product A and Product B have different variances of valuations. At the beginning of each period, they learn the valuations of both products and then bid for the first product. For the second product, a strategy method is used: The global bidder makes two different bids without knowing whether they won the first product or not. In

each auction, the highest bid among all bidders wins the product, but the winner pays the second highest bid. If the global bidder wins both products, they also receive a synergy. In the final part, we elicit players' risk preferences using [Holt and Laury \(2002\)](#).

Our main empirical findings are as follows: First, global bidders tend to bid above their valuations not only for the first product but also for the second. Second, global bidders experience negative payoffs more frequently when the product with lower variance is sold first, as predicted by theory. Third, efficiency increases with synergy, but selling the lower variance product second leads to a significant increase in efficiency, particularly in low synergy scenarios. Lastly, revenue rises significantly as synergy increases, while the order of product sales has no effect on revenue.

Our study is novel, as it is the first experimental study to analyze the impact of selling order in sequential auctions on global bidders' negative payoffs, as well as auction revenue and efficiency. We want to shape public policy by showing the correct selling order that minimizes bidders' ex-post loss, thereby preventing bankruptcies after auctions.

The remainder of this study is organized as follows. Chapter [2](#) reviews the literature. In Chapter [3](#), we discuss our hypothesis. In Chapter [4](#), we describe our experimental design and give details of the experimental procedures. In Chapter [5](#), we report the results of the experiment. Finally, in Chapter [6](#), we make our concluding remarks.

Chapter 2

Literature Review

Most of the existing papers on auctions concentrate on either identical or ex-ante identical products, where the order of sale would not matter (e.g., [Jeitschko and Wolfstetter, 2002](#); [De Silva, 2005](#), [Leufkens et al., 2010](#)), or simultaneous ascending auction ([Meng and Gunay, 2017](#)), where the order of selling products has no impact on revenue. In contrast, if there is a product heterogeneity in an auction, the selling order can affect the payoffs, efficiency, and revenue of the auction. Thus, our study experimentally identifies the selling order that minimizes negative payoffs and maximizes efficiency.

Few theoretical papers have explored the impact of selling orders in auctions, and their frameworks differ from ours. Moreover, none of them have investigated how the selling order affects negative payoffs, which is the main focus of our study. For example, [Bernhardt and Scoones \(1994\)](#) study the optimal selling order in a second-price sequential auction for heterogeneous products, where bidders can win only one product. Their findings suggest that the more dispersed product should be sold first to maximize expected revenue. In contrast, our model allows global bidders to win multiple products. Our results are based on the premise that a global bidder may bid above their standalone value, which could lead to an ex-post loss.

[Elmaghraby \(2003\)](#) investigates the effect of the auction order on efficiency with capacity-constrained bidders. Second-price sequential auctions are used to sell heterogeneous products; however, all bidders are local due to capacity constraints. Her findings are different from ours, since we deal with a trade-off between revenue and efficiency in the correct selling order. [Benoit and Krishna \(2001\)](#) study how selling order influences revenue in a complete information game with budget-constrained bidders. In contrast, our study has private information about the valuations of products without a budget-constrained assumption. [Pitchik \(2009\)](#) explores selling order when bidders are budget-constrained, and in equilibrium, each bidder wins only one product. In our case, bidders are not budget-constrained, and a global bidder may win both products. [Meng and Gunay \(2022\)](#) explore how the selling order affects efficiency when the number of bidders varies between products. Finally, [Gunay and Huamán-Aguilar \(2024\)](#) present experimental evidence indicating that the efficiency-maximizing auction order coincides with auctioning the product that attracts a larger number of bidders.

Given the predictions in the theoretical literature on sequential auctions, some experimental studies on synergies have been conducted (for overview, see [Kagel and Levin, 2016](#)). [Kagel and Levin \(2005\)](#) design a model of bidding with synergies by comparing uniform-price sealed bid auctions and ascending clock auctions. [Leufkens et al. \(2006\)](#) experimentally analyze how the presence of positive synergies affects bidding behavior in sequential auctions when two products are (ex-ante) identical. In their sequential auctions with four bidders, valuations of the second product are unknown when bidding in the first product, but winning the first product increases the winner’s valuation of the second product by a factor. They find that the over-bidding and the number of round bankruptcies increase when a positive synergy is present, while there is no difference for the different synergy levels. Their design has uncertainty because bidders cannot predict what their second product’s valua-

tion is beforehand. In our case, however, products are heterogeneous, and bidders know their valuations of the first and second products before they bid for the second product.

Chapter 3

Hypotheses

In this section, we provide a theoretical model based on [Gunay et al. \(2024\)](#) and state our hypotheses to be tested with experiments.

Consider a second-price sequential auction where two products of zero value to a seller, Product A and Product B, are sold. One global bidder, G, is risk-neutral and bids for both products. If the global bidder wins both, she will benefit from a synergy of $\theta > 0$ that is public information.¹ There are also $N > 0$ risk-neutral local bidders bidding for product $i = A, B$. The private valuations v_{Gi} for the global bidder and v_{ki} for each local bidder $k = 1, 2, \dots, N$ are determined by $N + 1$ independent draws from the distribution function F_i on the same support. The variance of Product B is smaller than the variance of Product A. In the theoretical paper of [Gunay et al. \(2024\)](#), the variance of F_B in fact approaches 0.

A symmetric subgame perfect Bayesian equilibrium method is used as the solution concept to derive the optimal bids. In this method, in (weakly undominated) equilibrium, local bidders bid truthfully, meaning that they bid exactly their valuations for their respective products. However, the global bidder's strategy is more complex. For the first product, she bids above her own valuation to win both products and capture the synergy. The global bidder's bid for the second product depends on

¹Even if it is private information, all theoretical results are valid.

whether she won or lost the first auction. She bids her marginal valuation truthfully for the second product. In other words, she bids $v_{Gj} + \theta$, if she wins Product i in the first auction and bids v_{Gi} otherwise, where $i, j = A, B$ and $i \neq j$.²

Hypothesis 1. The global bidder bids more than her valuation for the first product. Specifically, the bid for the first product i , b_{ij} , should satisfy the following inequality.

$$v_{Gi} \leq b_{ij}(v_{Gi}, v_{Gj}, N_i) \leq v_{Gi} + \theta$$

The global bidder wants to increase her chances of winning the first product because she knows that winning the second product will generate a synergy. Therefore, she bids above her valuation.

Hypothesis 2. If synergy increases the bid for the first product increases.

As synergy increases, the expected payoff also rises, which means that the bid for the first product should increase correspondingly.

Hypothesis 3. If the global bidder wins the first product, her bid for the second product will be her valuation plus the synergy as long as this sum is less than 100, otherwise the multiple equilibria will be anything above 100. If she loses the first product, her bid for the second product will be just her valuation.

When the global bidder loses the first product, she bids just her second product's valuation, which is also not affected by synergy θ . However, if she wins, she bids her second product's valuation and synergy. Therefore, we expect that the global bidder's bid for the second product increases with synergy when she wins the product in the first auction.

Now, we turn our attention to the hypothesis concerning the order in which the products are sold. If the variance of one product, Product j , approaches to 0, the

²For the proof, please see [Gunay and Meng \(2017\)](#).

global bidder's bid in the i leg of the ij auction approaches $v_{Gi} + \theta$. Selling that product first, whose variance is approaching zero, gives higher revenue than selling the other product first, which has higher variance, but results in lower social welfare. On the other hand, selling the lower variance product second gives a higher social welfare than selling the higher variance product second.

Hypothesis 4. When the product with low variance is sold second, the efficiency will be higher.

Hypothesis 5. When the product with low variance is sold second, revenue will be lower.

Hypothesis 6. When the product with low variance is sold first, the global bidder is more likely to incur a negative payoff.

To understand the last hypothesis, recall that the global bidder always bids above her valuation for the first product. As the variance of the first product's valuation approaches zero, the global bidder almost certainly wins the first product. However, her valuation for this product may be lower than the price she pays. When bidding for the second product, although she bids her valuation plus synergy, there remains a significant chance she may lose it due to the high variance in the second product's valuation. A local bidder with a higher valuation might win the second product, resulting in a loss for the global bidder. This outcome creates inefficiency in this selling order but leads to higher revenue, albeit at the expense of the global bidder's payoff. The last sentence also explains the reasoning of Hypothesis 4 and 5.

Chapter 4

Experimental Design & Procedures

We employ a 2x2 factorial design in our experiment.¹ We vary the selling order of the distribution of a product’s valuation (Order AB or Order BA) in one dimension, and the synergy level (high or low synergy) in another dimension. In half of the sessions, we run high synergy treatments, and in the other half, we run low synergy treatments. The number of participants for each treatment is summarized in Table 4.1.²

Table 4.1: Treatment Conditions & Number of Participants.

Synergy/Order	AB	BA
20	45 participants	40 participants
50	42 participants	44 participants

Each experimental session consists of two parts. Before starting each part, the experimenter reads the instructions aloud.³ The experiments start only after all

¹This study was approved by the University of Manitoba Human Research Ethics Committee under protocol number HE2025-0080, and by the METU Human Ethics Committee prior to the experiments.

²We named the treatment’s name based on the order of the selling product and synergy level. For example, in the AB-20 treatment, Product A is sold first and Product B is second when the synergy is 20.

³The instructions were in Turkish. An English translation is provided in Appendix A.1.

participants correctly answered comprehension questions regarding the first part.⁴

The first part of the experiment consists of 23 periods, with the first 3 periods being practice. In each period, participants bid in an auction to buy Product A and Product B. In the AB treatments, Product A is auctioned first, then followed by Product B.⁵ There are 2 local bidders and 1 global bidder for each product: The global bidder bids for both products, while the local bidders only bid for their own products. Before bidding in each period, values are assigned to global bidders for both products and to local bidders for the product they bid for.⁶ For each bidder (global and local), the valuations of Product A are drawn uniformly between 0 and 100, $U[0, 100]$. Valuations of Product B are drawn between 0 and 100 according to the Beta distribution function on the support $Beta[0, 100]$ (with mean 50). All values in the experiment are drawn independently and can be different in each period.⁷ In order to make it easier for participants to understand distribution differences, we show the following table in the instructions. Table 4.2 shows that the valuation of Product B is more likely to be between 35 and 65 compared to the valuation of Product A.

Table 4.2: Probability of Valuation to be at the given Interval for Each Product.

	Product A	Product B
P($45 < X < 55$)	10%	85%
P($35 < X < 65$)	30%	99.99%

At the beginning of each period, global bidders, after learning the valuations of both Product A and Product B, first bid for Product A in the AB order (Product B in the BA order). For both products, the bids can be any number between 0 and

⁴You can find the translated comprehension questions in Appendix B.1.

⁵In the BA treatments, Product B is auctioned first, then Product A.

⁶Since the valuations are private information in theory (and in real-life) global bidders do not know the values of the local bidders, and local bidders do not know the values of the global bidders. However, global bidders know their own valuations of both products at the beginning of each period.

⁷We utilized the identical values for every treatment, and the values were drawn prior to the studies. For instance, Product A's values in the AB treatment session and Product A's values in the BA treatment session are identical (the same is true for Product B).

150, allowing for bidding over valuations. At the same time, local bidders also bid for Product A. Local bidders are computers and submit their assigned values as bids.⁸ The bidder with the highest bid among global and local bidders wins Product A. However, the amount she pays is the second highest bid for this product as in the second price auction.

For eliciting global bidders' bids for the second product, we use the strategy method: In particular, global bidders are asked to make two different bids for the second product,⁹ without knowing whether they have won the first product, Product A in AB order: 1) How much would you bid for Product B if you won Product A? 2) How much would you bid for Product B if you lost Product A?

The global bidders' bids for Product B can also be between 0 and 150, we allow for overbidding for Product B as well. Similar to Product A auction, 2 local bidders in Product B auction bid their valuations. Here also following the second price auction process, the highest bidder between the bids submitted by global and local bidders wins Product B, and pays the second highest bid for this product. The actual bid of global bidders for the second product is determined as follows: If they actually won Product A, their bid for Product B in the case of winning Product A is taken into account; if they lost Product A, their bid for Product B in the case of losing Product A is taken into account.

If the global bidder only wins Product i , where $i = A, B$, her payoff at the end of the period is:

$$\text{Global Bidder's Value}_i - \text{Second Highest Bid}_i$$

⁸Kagel and Levin (2005) use humans as global bidders and computers as local bidders, with the latter bidding their true valuations. By utilizing computers as local bidders, concerns of emotional biases, such as spite, are eliminated, ensuring that bids are made solely based on valuations.

⁹The second product is Product B in the AB order, Product A in the BA order.

If the global bidder wins both products, her payoff at the end of the period is:

$$\begin{aligned} & (\text{Global Bidder's Value}_A - \text{Second Highest Bid}_A) + \\ & (\text{Global Bidder's Value}_B - \text{Second Highest Bid}_B) + \text{synergy} \end{aligned}$$

If the global bidder loses both products, her payoff at the end of the period is 0.

The synergy level differs by treatment. It is either 20 or 50.¹⁰

After each bidder has placed their bid for the second product, the period ends. At the end of each period, they are able to see whether they have won Product A and/or Product B, the winning bids for both products, the second highest bids (payment amounts), and their period payoffs.

In the second part, we elicit players' risk aversion levels using [Holt and Laury \(2002\)](#). In particular, players are asked to make a series of choices between Option A and Option B. Option A is a lottery with a 10 experimental currency unit (ECU) for a high payoff and 8 ECU for a low payoff. Option B is a lottery with 19.25 ECU for a high payoff and 0.5 ECU for a low payoff. For each option, the probability of winning the high payoff varies in each line from 1/10 to 1, with an increase of 1/10 in each row.

At the end of each session, players fill out a questionnaire regarding their demographics, including gender, age, and major, as well as their preferences for risk, competitiveness, and fear of losing. At the end of the experiment, two random periods from the first part and a row from the last part are drawn for their actual payment.

We ran 12 sessions in April and May 2024 at the Middle East Technical University (METU) Behavioral and Experimental Laboratory (BEL). In total, 171 students

¹⁰The highest stand-alone valuation is 100. The chosen synergy levels reflect 20% and 50% of the highest stand-alone valuation, respectively. We chose these levels as [Gunay et al. \(2024\)](#) use simulations for these levels as low and relatively moderate synergy levels. If we choose a higher synergy, then the global bidder will win most auctions, and it will be the efficient outcome as explained in [Gunay et al. \(2024\)](#).

participated.¹¹ They were invited by the university’s online recruiting system ORSEE (Greiner, 2015). Each session was computerized using z-Tree (Fischbacher, 2007) and lasted around 90 minutes. Throughout the experiment, values, bids, and payoffs were in “experimental currency unit (ECU)”. The payoffs were converted into Turkish Lira (TL) at the rate of 1 ECU to 4 TL. Players earned 205.80 TL¹² on average, including a 20 TL participation fee.

¹¹55.55% of players were male, and 71.35% of players’ ages ranged from 20 to 23.

¹²In 2024, the hourly minimum wage in Turkey was 75.56 TL.

Chapter 5

Results

In this section, we present the results of our experiments. Following the first part of this section, we analyze the effect of synergy and order on individual bids in each treatment condition. Lastly, we conclude by examining the change in negative payoffs, efficiency, and revenue between treatments.

When comparing means between treatments, we use a two-sided Wilcoxon ranksum test; when comparing values within treatments, we use a two-sided Wilcoxon sign-rank test; and when comparing percentages, we use a one-sided Fisher's exact test. For every regression analysis throughout the study, we use the subject-level clustering for standard errors. For every regression analysis, we present two models: In Model 1, Order (takes value 1 if Product A is sold first), Synergy (takes value 1 if the synergy level is high), and their interaction. In Model 2, independent variables are Model 1 and control variables. Control variables are the valuations of each product, Product A and Product B, players' self-scores about risk, competitiveness, and fear, gender (1 for female), and a dummy variable for the last 10 periods (1 for last 10 periods).

5.1 The Effect of Synergy, and Order of Products on Bids

Here, we discuss how synergy and order affect global bidders' bids for the first and second products, respectively.¹

First Product First, we compare the average bids for the first product with the equilibrium predictions. Table 5.1 summarizes equilibrium bid and average effort for the first product in each treatment when the equilibrium bids are less than 100. According to the two-sided signrank test, global bidders' average bids are significantly higher than the equilibrium in the AB-20 and BA-20 treatments whereas there is no significant difference between their bids and the equilibrium in the AB-50 and BA-50 treatments.

Table 5.1: Equilibrium and Average Bid for The First Product in Each Treatment.

	AB-20	AB-50	BA-20	BA-50
Equilibrium	67.30	94.70	58.62	78.83
Bid	71.52	92.64	68.55	86.35
p-value	0.053	0.254	0.0	0.129

Note 1: Reported p-values are for two-sided Wilcoxon signrank tests.

Note 2: The equilibrium bid is below 100.

Table 5.2 reports the average valuation and bid for the first product in each treatment. We can clearly see that the average bid for the first product in each treatment is significantly higher than the valuation of the first product. The result states that global bidders bid more than the valuation of the first product because of the hope of winning the second product and synergy regardless of the distribution and synergy of the product, which supports Hypothesis 1. Figure 5.1 shows a scatter plot of bids for the first product relative to the product valuations in each treatment. The percentages of bids above valuations are 90.44% in AB-20, 93.25% in BA-20,

¹After removing the outliers, we repeat the analysis and obtain comparable findings.

92.62% in AB-50, and 96.36% in BA-50. From these graphs and percentages, we can say that global bidders bid for the first product above the valuation in each treatment.

Table 5.2: Average Bid for The First Product in Each Treatment.

	Valuation of Product A	Bid for Product A	p-value
AB-20	50.32	71.52 (13.99)	0.0
AB-50	50.57	94.57 (22.62)	0.0
p-value		0.00	
	Valuation of Product B	Bid for Product B	p-value
BA-20	49.93	68.55 (14.85)	0.0
BA-50	49.99	86.35 (22.92)	0.0
p-value		0.0001	

Note 1: Reported p-values are for two-sided Wilcoxon ranksum and signrank tests.

Note 2: The equilibrium bid is not restricted.

Now, we can focus our attention on the impact of synergy on bids, Hypothesis 2. When global bidders bid for Product A in the AB order and bid for Product B in the BA order, they significantly increase their bids as synergy rises, which means that Hypothesis 2 holds (see Table 5.2). The difference between the bid and the valuation is significantly greater than zero. This finding also confirms that global bidders overbid for the first product in each treatment in order to win the first product by hoping to win both products.

Result 1. *In both selling orders, AB or BA, global bidders' bids are significantly higher than the equilibrium when the synergy is low. In all treatments, global bidders bid significantly higher than their valuations for the first product.*

Result 2. *In both selling orders, global bidders place significantly higher bids for the first product when synergy is high compared to when it is low.*

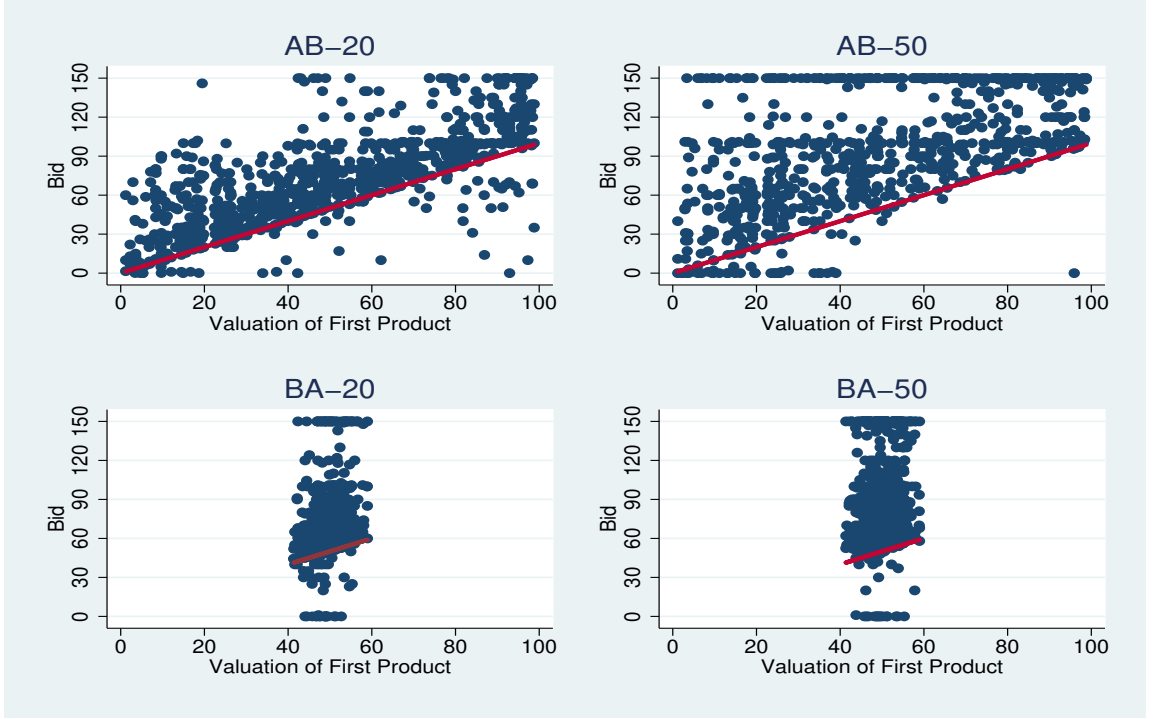


Figure 5.1: Bid for The First Product.

Second Product Table 5.3 and Table 5.4 summarize the average valuation, bid for the second product, and the difference between bid and valuation when the first product is won and lost in each treatment, respectively. In Table 5.3, global bidders bid significantly more for the second product than the valuation of that product in all treatments when they win the first product, hoping to win both products and obtain synergy in the end (two-sided signrank test, $p\text{-value} = 0.0$ in all cases).

We predict that if a global bidder wins the first product, she bids her valuation and synergy for the second product when the sum of valuation and synergy is less than 100. The equilibrium bid for the second product is calculated as the sum of a global bidder's valuation for a product and synergy. It is found that there is no significant difference between the observed bid and the equilibrium bid when the high variance product is sold first (two-sided signrank test, $p\text{-value} = 0.12$ in AB-20, and $p\text{-value} = 0.58$ in AB-50), and when treatment is BA-20 (two-sided signrank test, $p\text{-value} = 0.18$). In the BA-50 treatment, however, bid for the second product

Table 5.3: Average Bid for the Second Product When the First Product is Won in Each Treatment.

	Valuation of Product B	Bid for Product B	Difference
AB-20	49.95	68.19 (15.13)	18.25 (14.98)
AB-50	49.95	95.35 (28.49)	45.40 (28.54)
p-value		0.00	
	Valuation of Product A	Bid for Product A	Difference
BA-20	50.47	76.33 (18.73)	25.86 (18.12)
BA-50	50.62	93.19 (16.86)	42.58 (15.74)
p-value		0.00	

Note 1: Reported p-values are for two-sided Wilcoxon ranksum test.

Note 2: The equilibrium bid is not restricted.

is higher than the equilibrium, which is marginally significant (two-sided signrank test, p-value = 0.08).

When the first product is won either in the AB or BA order (see Table 5.3), global bidders bid significantly more for the second product as synergy increases. In AB order, the difference is less than the synergy, which is not significant regardless of the synergy level (two-sided signrank test, p-value = 0.12 in AB-20, and p-value = 0.32 in AB-50). In BA order, when the synergy level is high, the difference is significantly less than the synergy (two-sided signrank test, p-value = 0.004). However, when the synergy level is low, the difference is greater than the synergy but not significant (two-sided signrank test, p-value = 0.18).

Result 3. *When global bidders win the first product in the AB-20, AB-50, and BA-20 treatments, their bids for the second product closely align with the theoretical equilibrium, which equals the sum of valuation and synergy.*

Now, let us focus on the second part of Hypothesis 3, which concerns the bid for the second product when the first product is lost. In all treatments shown in

Table 5.4, global bidders significantly overbid for the second product, despite losing the first product, which rejects Hypothesis 3. When Product B is lost, global bidders bid significantly more for Product A in the BA-50 treatment than in the BA-20 treatment. However, when they lose Product A in the AB order, their bids for Product B do not change significantly with synergy.

Table 5.4: Average Bid for the Second Product When the First Product is Lost in Each Treatment.

	Valuation of Product B	Bid for Product B	p-value
AB-20	49.95	64.62 (18.09)	0.0
AB-50	49.95	73.85 (31.89)	0.0
p-value		0.204	
	Valuation of Product A	Bid for Product A	p-value
BA-20	50.47	63.83 (15.96)	0.0
BA-50	50.62	75.55 (27.13)	0.0
p-value		0.025	

Note 1: Reported p-values are for two-sided Wilcoxon ranksum and signrank tests.

Note 2: The equilibrium bid is not restricted.

This part of the hypothesis is comparable to one-product second-price auctions, as it pertains to the second stage of the auction, where there is only one product left. As stated in Hypothesis 3, bidding the product's true valuation in the second leg of the auction is an equilibrium. However, Table 5.5 shows that 84.78% of global bidders in the AB-20 treatment and 75.62% of bidders in the BA-20 treatment overbid for the second product when they lose the first. This tendency to bid above valuations has also been observed in laboratory experiments involving "one-product only" second-price auctions (Kagel and Levin, 1993; Cooper and Fang, 2008; Tan, 2020). For example, Kagel and Levin (1993) find that approximately 67% of the bids exceed the bidders' valuations in a second-price auction with five bidders. According to

the frequency of overbidding for the second product when the first is lost, global bidders tend to bid more aggressively when they have not yet secured a win, possibly motivated by a desire to avoid exiting the auction empty-handed.

Table 5.5: Frequency of Overbidding.

	AB-20	BA-20	p-value
For The First Product	49.67%	66.50%	0.0
For The Second Product When The First is Won	31.67%	46.38%	0.0
For The Second Product When The First is Lost	84.78%	75.62%	0.0

Note 1: Reported p-values are for one-sided Fisher’s exact test.

Note 2: The equilibrium bid is below 100.

Result 4. *When global bidders lose the first product, they bid significantly more than their own valuations for that product (equilibrium) in each treatment.*

5.2 Negative Payoff, Efficiency, and Revenue

Our main aim is to investigate the impact of selling order on negative payoff, efficiency, and revenue in sequential auctions. Thus, we show our findings for each cases, respectively.

Negative Payoff Global bidders tend to bid above their valuations not only for the first product but also for the second product, so it is possible that they may make losses (negative payoff), which leads to bankruptcy. The winner of the first product may not win the second one or may win it but still the total payoff from both products may be negative. Thus, for each treatment, we calculate the percentage of global bidders received a negative total payoff in each period in Table 5.6.

According to the one-sided Fisher’s exact test, the percentage of global bidders with negative payoff significantly decreases as synergy rises in both orders. On the other hand, when Product A is sold second, this percentage increases significantly

Table 5.6: Percentage of Global Bidders with Negative Payoff.

	20	50	p-value
AB	18.56%	12.50%	0.0
BA	37.25%	24.77%	0.0
p-value	0.0	0.0	

Note 1: Reported p-values are for one-sided Fisher's exact test.

Note 2: The equilibrium bid is not restricted.

independently of synergy levels, consistent with Hypothesis 6. The regression estimations in Table 5.7 also confirm these findings.

Table 5.7: Regression Estimation For Negative Payoff.

Dependent variable	Negative Payoff	
	Model 1	Model 2
Order (1 if Product A is sold first)	-0.187*** (0.039)	-0.180*** (0.038)
Synergy (1 if synergy is 50)	-0.125*** (0.028)	-0.122*** (0.026)
Order $\times$ Synergy	0.064 (0.047)	0.06 (0.045)
Valuation of Product A		-0.0047*** (0.0003)
Valuation of Product B		-0.0166*** (0.002)
Risk Self Scale		0.008 (0.005)
Competitive Self Scale		0.007 (0.005)
Fear Self Scale		0.0006 (0.005)
Female		0.048* (0.025)
Last 10 Periods		-0.031** (0.013)
Constant	0.373*** (0.023)	1.323*** (0.119)
Control	No	Yes
Observations	3420	3420
Num. of cluster	171	171
R^2	0.045	0.176

Note: Standard errors in parentheses are clustered at the subject level. *0.10, **0.05, ***0.01. Moreover, the equilibrium bid is not restricted.

Table 5.7 also shows that although global bidders tend to bid above their valuations for both products, they significantly decrease this overbidding behavior in the last 10 periods. Lastly, female bidders’ negative payoff is significantly higher than that for male bidders.

Result 5. *Global bidders experience negative payoffs more frequently when the low variance product is sold first compared to when it is sold second, in both synergy levels.*

Efficiency and Revenue We now examine changes in efficiency² (Table 5.8) and revenue³ (Table 5.9) across treatment conditions. In both selling orders, efficiency increases significantly as synergy rises. When synergy is 50, efficiency does not differ by selling order. However, consistent with Hypothesis 4, when synergy is 20, efficiency is significantly higher in the AB order than in the BA order.

Table 5.8: Efficient Outcome In Each Treatment.

	20	50	p-value
AB	61.33%	69.52%	0.0
BA	55.50%	68.30%	0.0
p-value	0.008	0.309	

Note 1: Reported p-values are for one-sided Fisher’s exact test.

Note 2: The equilibrium bid is not restricted.

Revenue is calculated as the highest second bid across all players in each period. As seen in Table 5.9, synergy has a significant positive effect on revenue, but the order in which products are sold — each drawn from different distribution functions — does not significantly affect revenue.

To summarize our findings, Table 5.10 reports the estimation results of multivariate regressions with efficiency and revenue as the dependent variables, respectively.

²An efficient outcome occurs when the global bidder with the highest valuation wins the auction.

³Revenue is calculated as the sum of the second-highest bids for Product A and Product B in each treatment.

Table 5.9: Revenue In Each Treatment.

	20	50	p-value
AB	108.79 (5.89)	113.55 (6.27)	0.0014
BA	109.97 (5.47)	114.47 (5.12)	0.0006
p-value	0.459	0.554	

Note: Reported p-values are for two-sided Wilcoxon ranksum test.

Note 2: The equilibrium bid is not restricted.

Efficiency and revenue both significantly increase as synergy rises. Order has a significant positive effect on efficiency, whereas its negative effect on revenue is not significant, consistent with our earlier results. Both efficiency and revenue also increase significantly with the valuations of Product A and Product B. According to the estimation results for the Last 10 Periods, we observe a significant learning effect on efficiency but not on revenue.

Result 6. *Efficiency increases with synergy. However, correct order significantly increases efficiency when synergy is low.*

Result 7. *Revenue increases significantly as synergy rises but does not change with order.*

Table 5.10: Estimation Results For Efficiency and Revenue.

Dependent variable	Efficiency		Revenue	
	Model 1	Model 2	Model 1	Model 2
Order	0.0583*	0.0628*	-1.166	-0.527
(1 if Product A is sold first)	(0.0348)	(0.0323)	(1.222)	(1.182)
Synergy	0.128***	0.128***	4.507***	4.365***
(1 if synergy is 50)	(0.0292)	(0.0271)	(1.149)	(1.108)
Order $\times$ Synergy	-0.0460	-0.0475	0.248	0.212
	(0.0459)	(0.0438)	(1.732)	(1.686)
Valuation of Product A		0.00567***		0.233***
		(0.000359)		(0.0183)
Valuation of Product B		0.0158***		0.184*
		(0.00225)		(0.101)
Risk Self Scale		-0.00833		0.0256
		(0.00508)		(0.228)
Competitive Self Scale		0.00126		-0.0352
		(0.00560)		(0.216)
Fear Self Scale		-0.00519		-0.0938
		(0.00474)		(0.176)
Female		-0.0242		2.599***
		(0.0231)		(0.857)
Last 10 Periods		0.0427***		-0.759
		(0.0148)		(0.788)
Constant	0.555***	-0.459***	110.0***	88.63***
	(0.0206)	(0.125)	(0.857)	(5.400)
Control	No	Yes	No	Yes
Observations	3420	3420	3420	3420
Num. of cluster	171	171	171	171
R^2	0.013	0.146	0.011	0.097

Note: Standard errors in parentheses are clustered at the subject level. *0.10, **0.05, ***0.01. Moreover, the equilibrium bid is not restricted.

Chapter 6

Conclusion

In this study, we experimentally examine the effect of the selling order of heterogeneous products on global bidders' bids, payoffs, efficient outcomes, and revenue in second-price sequential auctions. Building on the theoretical model proposed by [Gunay et al. \(2024\)](#), our main theoretical predictions are as follows: Global bidders submit bids above their own valuations for the first product and increase their bids with synergy. For the second product, if a global bidder has acquired the first, she bids the sum of her own valuation and synergy, provided this total does not exceed 100. If the bidder fails to win the first product, she bids only her own valuation for the second. Auction efficiency is higher and revenue is lower when the product with lower variance is sold second. Conversely, selling the lower variance product first increases the likelihood of global bidders incurring negative payoffs, potentially leading to bankruptcy.

When we test those predictions, several insights emerge from our experiments. First, global bidders bid for the first product significantly above the equilibrium when the synergy is low in both orders. They also bid more than their valuations under all conditions, which is consistent with our hypothesis. As predicted, their bids for the first product increase with the level of synergy, independent of the selling order.

Second, our experimental design allows us to observe bids for the second product depending on whether the first product is won or lost. When the first product is won, global bidders bid the sum of their own valuation and synergy for the second product in the AB-20, AB-50, and BA-20 treatments provided that this sum is less than 100. When the first product is lost, they consistently overbid for the second product in all cases. This finding contradicts our hypothesis, but such overbidding behavior has also been observed in second-price auction studies.

Lastly, global bidders experience negative payoffs in both synergy levels when the product with the lower variance is sold first. This negative outcome can be mitigated by adjusting the selling order. We observe a higher efficient outcome when the lower variance product is sold second under low synergy — compared to when it is sold first.

Our findings carry significant policy implications, particularly for governments and regulatory authorities involved in the design of sequential auctions featuring interdependent products. In light of these findings, a government should consider selling the higher variance product first in order to avoid possible bankruptcy situations and to improve the likelihood of achieving an efficient outcome. Thus, the ordering of products in sequential auctions may serve as an effective policy instrument for enhancing market stability, allocative efficiency, and overall bidder welfare.

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Appendix

A.1 Experimental Instructions

Below are the English translations of the instructions for the AB-20 treatment. Note that the order of the products and the synergy level vary from session to session. We specify the instructions for the other treatments within square brackets.

General Instructions

Welcome to our experiment.

In this experiment, we want to examine the process of strategic decision-making. If you follow the instructions closely, you can earn money. Your earnings may differ from other participants'. The amount you earn depends on your own decisions, the decisions of other participants, and chance. You will be paid all the money you have earned in cash immediately after the session ends.

The experiment will proceed in two parts. Each part will be explained just before that part begins. During the experiment, your earnings will be calculated in an experimental currency (EUC). The EUC will be converted to Turkish Lira (TL) at a rate of 1 EUC to 4 Turkish Lira. You will also be paid an additional fixed show-up fee of 20 TL for your participation. In the final part of the experiment, you will be asked to answer a few questions.

Thank you for participating.

Part 1

This part will consist of **23 periods**. The first 3 periods will be trial periods, and your earnings here will not be used to calculate your total earnings. In each period, you will bid in the auction to buy Product A and Product B. Product A [*Product B in the BA treatment*] will be sold first, then Product B [*Product A in the BA treatment*]. There will be **2 local bidders** and **1 global bidder** for each product:

- The global bidder will place bids for both products.
- Local bidders will place bids only on their own product.

Values, bids, and earnings will be in terms of experimental currency (EUC). Before bidding in each period, global bidders will be assigned values for both products, and local bidders will be assigned values for the product they will bid on: **Global Value** and **Local Value**. Global bidders will not know the value of local bidders, and local bidders will not know the value of global bidders. Local bidders will be computers and will always bid their own value.

For each bidder (both global and local)

- The value of Product A will be randomly chosen between 0 and 100, with an equal chance for each number.
- The value for Product B will be randomly chosen between 0 and 100 according to Beta(100,100) function.

Table A.1: Probability of Each Product.

	Product A	Product B
P($45 < X < 55$)	%10	%85
P($35 < X < 65$)	%30	%99.99

Product A [*Product B in the BA treatment*]

At the beginning of each period, global (you) bidders will first bid for Product A [*Product B in the BA treatment*] after learning the values of both Product A and Product B. You may bid any number **between 0 and 150**. At the same time, local bidders will also bid for Product A [*Product B in the BA treatment*]. Local bidders will become computers and submit their assigned values as bids. For example, if local bidders value Product A [*Product B in the BA treatment*] at 30.75 and 80.00, respectively, their bids will be 30.75 and 80.00, respectively.

The **highest bidder** among the bids submitted by global (you) and local bidders will win Product A [*Product B in the BA treatment*]. However, the amount that she will pay will be the **second-highest** bid for this product. If bids are the same, the winner will be chosen randomly.

Product B [*Product A in the BA treatment*]

Global bidders (you) will be asked to make two different bids for Product B without knowing whether they won Product A or not.

- If you won Product A [*Product B in the BA treatment*], how much would you bid for Product B [*Product A in the BA treatment*]?
- If you lost Product A [*Product B in the BA treatment*], how much would you bid for Product B [*Product A in the BA treatment*]?

You may bid any number **between 0 and 150**. 2 local bidders will also bid for Product B [*Product A in the BA treatment*]. These will be computers and will bid the assigned values to them. For example, if local bidders value Product B [*Product A in the BA treatment*] at 31.25 and 75.19 respectively, their bids will be 31.25 and 75.19 respectively.

The **highest bidder** among the bids submitted by global (you) and local bidders will win Product B [*Product A in the BA treatment*]. However, the amount that she will pay will be the **second-highest** bid for this product. If bids are the same, the winner will be chosen randomly.

Global bidders will bid on Product B [*Product A in the BA treatment*] without knowing whether or not they actually won Product A [*Product B in the BA treatment*]. If they have won Product A [*Product B in the BA treatment*] with their bid for Product A [*Product B in the BA treatment*], their first bid will be taken into consideration, and if they lost, their second bid will be taken into account. For example, the Global bidder (you) bids 120 EUC for Product B [*Product A in the BA treatment*] if you won Product A [*Product B in the BA treatment*] and 80 EUC if you lost Product A [*Product B in the BA treatment*]. At the end of the period, she learned that she had won Product A [*Product B in the BA treatment*]. In this case, her bid for Product B [*Product A in the BA treatment*] will be taken as 120 EUC.

Payoff

After each bidder submits their bid, they will be able to see whether they have won Product A and Product B, the winning bids for both products, the second-highest bids, their earnings from the products, and their earnings for that period. All values in the session will be drawn independently and may differ from each other in every period.

If the global bidder (you) wins a single product, the period gain is:

$$\text{Global Value}_{A[B]} - \text{Second Highest Bid}_{A[B]}$$

If the global bidder (you) wins both products, your payoff at the end of the period is:

$$\begin{aligned} &(\text{Global Value}_A - \text{Second Highest Bid}_A) + \\ &(\text{Global Value}_B - \text{Second Highest Bid}_B) + 20 \text{ [50]} \end{aligned}$$

The global bidder (you) will only receive the **+20 [+50 in the AB-50 and**

BA-50 treatments] value if you win both products. You will not receive this value if you win only a single product.

Case 1

Assume that for Product A, the global bidder's value is set to 55, while the local bidders' values are set to 60 and 15, respectively. Let the value of the global bidder (you) for Product B, determined according to the Beta(100,100) function, be 51. Local bidders are computers, and they will bid their values as bid. You will know your own product values for both Product A and Product B at the beginning of the period.

If you win both products, you will receive an additional 20 **[50]** EUC on top of your earnings from the products at the end of the period. You, the global bidder, have bid 65 for Product A. Let the local bidders' values for Product B be 50 and 45, and they will bid these values just like they did for Product A. Since the highest bid between 65, 60, and 15 is 65, you win Product A and pay the second-highest bid, which is 60.

	Product A			Product B		
	Local 1	Local 2	Global (You)	Local 3	Local 4	Global (You)
Values	60	15	55	50	45	51
Bids	60	15	65	50	45	Win - 55 Lose - 51
Payoff	0	0	$55 - 60 = -5$	0	0	$51 - 50 = 1$

Since you won Product A, your bid of 55 for Product B will be compared with other bids. Since yours is the highest, you will win Product B and pay the second-highest bid for Product B. Since you win both products in the period, you earn an additional 20 **[50]** EUC:

$$\text{Your total earnings} = (65 - 60) + (55 - 50) + 20 \text{ **[50]**} = 30 \text{ **[55]**}$$

Case 2

The global bidder bids 55 and loses Product A. For Product B, you bid 55 if you

win Product A and bid 49 if you lose. Since the global bidder lost Product A, the bid of 49 will be compared with the other bids placed (50, 45, 49). For Product B, the local bidder (Local 3) is the winner and will pay the second highest bid ($50 - 49 = 1$).

	Product A			Product B		
	Local 1	Local 2	Global (You)	Local 3	Local 4	Global (You)
Values	60	15	55	50	45	51
Bids	60	15	55	50	45	Win - 55 Lose - 49
Payoff	$60 - 55 = 5$	0	0	$50 - 49 = 1$	0	0

The global bidder (you) will not gain anything since you lost Product B. Additionally, since you did not win both products, your total earnings at the end of the period will be 0.

Case 3

The global bidder (you) bids 65 and wins Product A. For Product B, you bid 49 if you win Product A and bid 51 if you lose. Since the global bidder won Product A, 49 will be compared with the other bids placed (50, 45, 49). The local bidder for Product B (Local 3) will be the winner and pay the second highest bid ($50 - 49 = 1$).

	Product A			Product B		
	Local 1	Local 2	Global (You)	Local 3	Local 4	Global (You)
Values	60	15	55	50	45	51
Bids	60	15	65	50	45	Win - 49 Lose - 51
Payoff	0	0	$55 - 60 = -5$	$50 - 49 = 1$	0	0

The global bidder (you) will not gain anything as you are the loser of Product B. Since you won a single product, your total earnings at the end of the period will be as follows: Your total earnings = $55 - 60 = -5$

At the end of the experiment, 2 periods will be randomly chosen and your real earnings will be calculated by converting EUC earned in these 2 periods to Turkish

Liras.

Part 2

In this section you are asked to make a series of choices. How much you earn will depend on chance and the choices you make. For each line, please state whether you prefer Option A or Option B. There are 10 lines in the table, but only one line will be randomly selected for payment, and you will not know which line will be drawn. Thus, you should be careful about the choice you make in every line.

Table A.2: Lottery Choices for Risk Elicitation

Option A	Option B
10% prob. 10 EUC, 90% prob. 8 EUC	10% prob. 19.25 EUC, 90% prob. 0.5 EUC
20% prob. 10 EUC, 80% prob. 8 EUC	20% prob. 19.25 EUC, 80% prob. 0.5 EUC
30% prob. 10 EUC, 70% prob. 8 EUC	30% prob. 19.25 EUC, 70% prob. 0.5 EUC
40% prob. 10 EUC, 60% prob. 8 EUC	40% prob. 19.25 EUC, 60% prob. 0.5 EUC
50% prob. 10 EUC, 50% prob. 8 EUC	50% prob. 19.25 EUC, 50% prob. 0.5 EUC
60% prob. 10 EUC, 40% prob. 8 EUC	60% prob. 19.25 EUC, 40% prob. 0.5 EUC
70% prob. 10 EUC, 30% prob. 8 EUC	70% prob. 19.25 EUC, 30% prob. 0.5 EUC
80% prob. 10 EUC, 20% prob. 8 EUC	80% prob. 19.25 EUC, 20% prob. 0.5 EUC
90% prob. 10 EUC, 10% prob. 8 EUC	90% prob. 19.25 EUC, 10% prob. 0.5 EUC
100% prob. 10 EUC, 0% prob. 8 EUC	100% prob. 19.25 EUC, 0% prob. 0.5 EUC

After you have completed all your choices, the computer will randomly draw a number from 1 to 10 to determine which line of the lottery will be selected for payment.

- Option A is a lottery with 10 EUC for high returns and 8 EUC for low returns. The probability of winning high profits varies with each line.
- Option B is a lottery with 19.25 EUC for a high return and 0.5 EUC for a low return. The probability of winning high profits varies with each line.

B.1 Comprehension Questions

Before we started with the first part of the experiment, we asked the players to answer some control questions. Below we provide the English translations of control questions for the AB-20 treatment. The square bracket is used for the higher synergy treatment.

Please answer the following questions. When you are finished, please raise your hand. The experimenter will come to you and check whether everything is correct or not.

1. Answer the questions according to the scenarios in the table below.

		Product A		
		Local 1	Local 2	Global (You)
Scenario 1	Values	55	60	50
Scenario 2	Values	40	85	90
Scenario 3	Values	40	90	60

- a. According to Scenario 1, if your offer for Product A is 55, what is your profit?
- b. According to Scenario 2, if your offer for Product A is 105, what is your profit?
- c. According to Scenario 3, what is Local 2's offer for Product A?

2. When you, the global bidder, win both Product A and Product B, you will receive 20 EUC [**50 EUC**] in addition to your payoff from the products. Answer the questions according to the scenarios in the table below.

		Product A			Product B		
		Local 1	Local 2	Global (You)	Local 1	Local 2	Global (You)
Scenario 1	Values	70	60	80	40	45	50
Scenario 2	Values	80	15	85	50	55	50
Scenario 3	Values	60	15	55	50	55	50
Scenario 4	Values	60	15	55	50	55	70

- a. According to Scenario 1, if you bid 80 for Product A and 50 for Product B if you win Product A and 50 if you lost Product B, what is your period profit?
- b. According to Scenario 1, if you bid 80 for Product A and 120 for Product B if you win Product A and 120 if you lost Product B, what is your period profit?
- c. According to Scenario 2, if your bid for Product A is 85 and your bid for Product B is 75 if you win Product A and 60 if you lose Product B, what is your period profit?
- d. According to Scenario 3, if your bid for Product A is 55 and your bid for Product B is 50 if you win Product A and 65 if you lose Product B, what is your period profit?
- e. According to Scenario 3, if your bid for Product A is 55 and your bid for Product B is 100 if you win Product A and 115 if you lose Product B, what is your period profit?
- f. According to Scenario 4, if your bid for Product A is 30 and your bid for Product B is 45 if you win Product A and 65 if you lose Product B, what is your period profit?