Is List Pricing and Discounting Procompetitive? Tacit Collusion in a Bertrand-Edgeworth Duopoly.

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Abstract:

List-pricing and discounting is a common practice in retail and wholesale markets. Under this pricing mechanism, a posted list price is offered to sellers in a prior stage which can then de discounted at a later in a second stage. The practice of list pricing and discounting is viewed as collusive theoretically, however, its interpretation amongst competition authorities varies from being pro-competitive to being a collusion facilitating device. We experimentally test how list pricing and discounting impact prices in a capacity constrained Bertrand-Edgeworth duopoly with symmetric and asymmetric firms. We find evidence of collusion under list pricing and discounting with symmetric as well as with asymmetric firms relative to a baseline case without the discounting stage.

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1. Introduction

List pricing, accompanied with discounts at a later stage, is a common pricing practice in many industries (retail, real estate[2], pharmaceuticals[3], airplane manufacturers, service industry etc.). It is also common for retail firms, Ikea and Amazon are two examples, to post a list price which then be discounted at a later stage. List prices indicate firm commitment to a price for a given period of time. They can be lowered through offering of discounts as uniform discounts to all consumers or through bargaining. It is interesting to note that the U.S. Department of Justice potentially views it as a possible collusion facilitating device.[4] The FTC is of the opinion that list prices can provide a means of reaching consensus and observing prices thus facilitating coordinated action.[5] Harrington (2011), meanwhile, argues that the adoption of posted pricing communicates the necessary intent and reliance to conclude concerted action. Finally, Judge Posner has also discussed the role of list prices versus transaction prices in the High Fructose Corn Syrup matter (295F.3d 651: 2002 U.S. App.). He noted that even if most customers do not pay list prices, list prices may have an impact on transaction prices and thus fixing list prices may influence competition. The empirical relevance of this type of pricing behavior in concentrated industries with a single dominant firm is shown in Sorgard (1997). The general consensus seems to be that list-prices can potentially lead to increased prices.

There has been theoretical research that involves models assuming sequential timing of firm moves. This approach is followed in Shubik and Levitan (1980), Deneckere and Kovenock (1992), and Canoy (1996), among others. Meanwhile, García-Díaz, Hernán-González and Kujal (2009) provide an alternative to the sequential timing hypothesis by studying a natural extension of a Bertrand–Edgeworth model for which pure strategy equilibrium always exists. They study list-pricing and discounting when firms are (even marginally) asymmetric (García-Díaz, Hernán-González and Kujal, 2009). Their result is similar to what is obtained in Deneckre and Kovenock (1992) in a sequential framework with commitment. Both approaches find similar results in that the pricing institution they study (price leadership or list prices) act as a facilitating collusion device between the firms.

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[2] https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1540-6229.2010.00279.x

[3] https://www.arnoldporter.com/en/perspectives/publications/2015/12/the-cma-takes-another-look-at-discounts, https://jamanetwork.com/journals/jamanetworkopen/article-abstract/2757480, https://jamanetwork.com/journals/jama/article-abstract/2762310

[4] Of special interest are practices where list pricing, and discounting, information is shared among firms. See, for example, the information exchange program studied by the U.S. Department of Justice with respect to publishing list price information, as proposed by the accounting firm HIOB (at http://www.usdoj.gov/atr/public/busreview/211191.htm).

[5] "LP&D might provide a means of reaching consensus on prices thus facilitating coordinated actions" in (Scheffman and Coleman, 2003).

One of problems that we face as regards such pricing practices and their subsequent impact on prices is the scarcity of information on costs, production, and transaction prices. Even with reliable data at hand, too many factors may change to allow for a clean "natural experiment". For example, a change in the pricing institution might simultaneously change the market structure (i.e. number of competitors, concentration, industry capacity- and product heterogeneity, among other effects). Any, or a combination, of these effects might affect market performance, therefore, the use of experimental methods to isolate the effects of alternative pricing institutions becomes of increased importance and their use becomes important to gain insights into individual behaviour.

In this paper we experimentally study the effect of list pricing and discounting on prices and collusive behaviour. The goal of our experiments is not to test any theoretical model. We study the effect of list-prices and the introduction of a discounting stage on overall prices with efficient demand in an indefinitely repeated game (that can potentially result in many equilibria). We chose this approach as the indefinitely repeated approach better suits what occurs in real world industries where individuals have repeated interaction over an indefinite time frame[6]. We also feel that a finite repeated experiment would result in similar outcomes as the experimental evidence indicates that cooperative outcomes are achieved even in one-shot (experimental) interactions[7].

We look at both symmetric and asymmetric Bertrand-Edgeworth duopolies. In our baseline experiments (Baseline-1 and -2) we look at the standard Bertrand-Edgeworth duopoly where firms post prices. We then extend this to allow for an additional pricing stage where firms can only discount on the posted price. We study both the symmetric and asymmetric cases. In the asymmetric case we keep the same marginal costs and firms only differ in their capacities.

2. Experiment procedure

Experiments were run at the Economic Science Institute, Chapman University. Participants were recruited by email from a pool of more than 2,000 students who had previously signed up for economic experiments. Emails were sent to a randomly selected subset of the pool of students. In total, 78 students participated in 36 duopoly experiments. The experiments Baseline experiments lasted 1 hour while the list-pricing and discounting experiments lasted for 90 minutes.

The instructions were displayed on subjects' computer screens, and they were told that all screens displayed the same set of instructions. They had exactly 20 minutes to read the instructions (see Appendix) with the timer being displayed on the screen. Three minutes before the end of the

[6] Some fixed match quantity setting experiments are justified on this basis (see for example, page 438, fn. 8, in Huck, Normann and Oechssler, 2004). They argue in favour of fixed matches and state that there is no rematching in real industries.

[7] A good example is the cooperative outcomes obtained in the one-shot prisoner's dilemma experiments.

instructions period, a monitor entered into the room announcing the time remaining and handing out a printed copy of the summary of the instructions. None of the participants asked for extra time to read the instructions. At the end of the 20-minute instruction round, the experimenter closed the instructions file from the server, and subjects typed their names to start the experiment. The interaction between the experimenter and the participants was negligible. Average payoffs (including the show-up fee) varied from a low of $15.28 (symmetric baseline) to a high of $17.60 (asymmetric list price and discounting treatment).

3. Experimental Design

As mentioned earlier, our experiments are not a test of a specific theoretical model. We use the standard capacity constrained framework, with efficient demand, to study the impact of list pricing and discounting on final prices. We run fixed pair duopolies that can be symmetric, or asymmetric, in their capacities. Keeping the aggregate capacities the same, the asymmetric design is obtained by simply redistributing capacity from one firm to another. In our main treatments, firms can announce a listed price in the first stage that can then only be discounted in the second stage. We check for whether the practice of list pricing with subsequent discounts results in significantly higher prices over the baseline experiments. As is standard practise in these experiments consumers are automated and accept any trade that gives them a surplus of zero or greater.

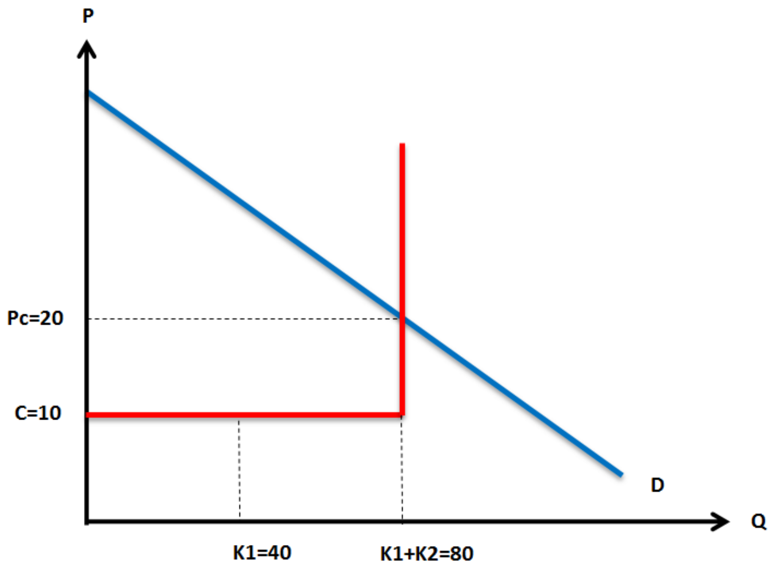
Capacity constrained sellers offer homogeneous products. In the benchmark case (standard Bertrand-Edgeworth duopoly) in each period a seller chooses price and consumers are first allocated to the seller with the lowest price according to a proportional rule and its capacity constraint. The remaining consumers are allocated to the seller with the highest price. In the Bertrand-Edgeworth duopoly with list pricing and a subsequent discounting stage, sellers first simultaneously choose the list prices and in the second stage they simultaneously choose the prices at which they sell their goods. Consumers are allocated according to the proportional rationing rule. The horizon is indefinite, and the history is common knowledge. Section 2.1 provides a detailed description of the setting. The various treatments to be run are described in Section 2.2, and the procedures deployed in conducting the experiments are summarized in Section 2.3.

3.1. Environment

The experiment consists of a multi-period posted offer market with fixed matching. Participants are told that the experiment will last for at least *50* periods after which there is a *80%* chance of continuation to each subsequent period.[8] Sellers are told that a random draw determines this outcome. Sellers offer identical products and face market demand *P(Q)=100-Q*, and are informed that the buyers are simulated.[9]

Each seller's cost function is, *Ci(q)=cq, for i=1,2,...n,* with *c* being the constant marginal cost for each unit sold and *q* the quantity sold. There is common knowledge of demand and supply parameters (including capacity constraints). In all treatments, total industry capacity for a duopoly is fixed at 80 units, while the allocation of the units across sellers varies. For example, for the uniform case, a firm, *i's*, capacity is k_i *(=40)* and marginal cost c_i (=10) $\forall i$. The market demand and the industry cost curve are depicted in Figure 1.

Figure 1.



In each period, subjects simultaneously choose a price at which goods are to be sold. Subjects have *60* seconds to select a price. If a subject chose not to post an offer then she earns zero profits for that period. Once subjects post their price, the market clears using computerized buyers buying first from the lowest posted price, and then from the seller with the second lowest price according to the proportional rationing rule. The proportional rationing rule is implemented according to the following specification of the residual demand, $R(p_i, p_j, k_j)$,

$$R(p_i, p_j, k_j) = \max\left\{D(p_i)\left(1 - \frac{k_j}{D(p_j)}\right), 0\right\} \quad (1)$$

[8] The shortest experiment ran for 50 periods while the longest lasted for 58 periods.
[9] There are then 100 computerized buyers with one buyer with a valuation of 100, one with a valuation of 99, and so forth.

Where p_i is the price and k_i is the capacity of firm i. Sellers only incur costs for units sold. A subject's total number of units produced and sold is indicated by their residual demand. Thus, according to equation (1), the demand of firm *i* at price p_i is reduced by a fraction determined by the unsatisfied demand of firm *j* due to the capacity constraint.

At the end of each period each subject is informed about the price offer of the other subjects, as well as all units sold and profit earned. Subjects can also review the entire history at any point in time. In addition, subjects are provided with a profit calculator where they can input price offers for all sellers and learn the resulting profits. Subjects are informed that: *"The profit calculator allows you to estimate your (and others) profits. To do so you can input your price and make guesses for the other sellers."* The calculator allows them to try various combinations of price and quantity offers and see how it affects their profits.

3.2. Treatments

As mentioned earlier, our interest is to see whether the introduction of the list pricing and discounting institution leads to higher prices on average. Though only applicable to our baseline, from Theorem 1 in Deneckere and Kovenock (1992), we know that the support of the mixed strategy in the baseline will be the Edgeworth price, p_i^E, and the monopoly price, p^m, where:

$$p_i^E = min\left\{p\colon \min\big(D(p), k_j\big)\left(p - c_j\right) = \max_{x \in \left[p - p_j^L\right]} R(x, p, k_i)(x - c_j)\right\}. \qquad (2)$$

Demand is allocated in all treatments using the proportional rationing rule. The mechanism for allocation of units is efficient where the low-price firm sells first, and the higher price firm sells to the residual demand. We run the following experiments.

<u>**Baseline:**</u> The Baseline experiments are run with both symmetric and asymmetric capacities. In the symmetric baseline case (denoted by BS) firms post prices given cost and capacities. Firms simultaneously post price offers, p_i^D, and have identical costs and capacity, $k_i=40$, $c_i=10$ $\forall i=1,2,$ with total capacity of 80 units for all market structures. The pricing equilibrium in the one-stage game is in mixed-strategies. According to Deneckre and Kovenock (1992), theorem 1, the support is the monopoly and the Edgeworth price, (p_i^E, p^m).

<u>**Symmetric treatment (BS):**</u> Each firm has capacity and cost: $k_i=40$ and cost $c_i=10,$ $\forall i=1,2.$

Asymmetric treatment (BA): The small firm now has capacity $k_i=50>k_j=30$, and $c_i=10, \forall i=1,2$.

List Prices and Discounts: As before the aggregate capacity in the market is (for all market structures) 80 units. In the first (Symmetric) and second (Asymmetric) treatment a two-stage pricing game (LP) is implemented. Firms can post list prices, p_i^L, $i=1,2$, in the first stage and these can then potentially be discounted, p_i^D, $i=1,2$, in the second stage. We denote by p_i^L the list price announced by firm i, p_i^D the discount price set by firm i.

List pricing-Symmetric treatment (LPS): Each firm has capacity and cost: $k_i=40$ and cost $c_i=10, \forall i=1,2$.

List pricing-Asymmetric treatment (LPA): The smallest firm i has capacity $k_i=50>k_j=30$, and $c_i=10, \forall i=1,2$.

4. Results

Recall that the length of the horizon is 50 periods with certainty and is then stochastically terminated. We report results only for the first 50 periods, periods 1-25 and 26-50.

4.1 Symmetric Case: Baseline and List Price with Discounting

All analysis is conducted with sales weighted prices. We first look at the pricing behavior of duopolies under the symmetric capacity experiments. For the baseline, symmetric case, Table 1 reports the average and median market price, and the standard deviation. We find that the average and median market prices are 32.9 and 32.2, respectively; for periods 1-25. These are also higher than the theoretical competitive equilibrium price of 20 for periods 26-50, as well as from periods 1-50. In all cases prices are below the theoretical monopoly equilibrium price (55). Conducting a t-test for the hypothesis that average market price exceeds a price of 20, is not rejected.[10]

Now we look at average prices for the symmetric list pricing and discounting (LPS) case (Table 1). We find that average market prices are significantly higher than what is observed in the baseline experiments.[11] We observe an average price of 38.54 over periods 1-25; 41.55 over periods 26-50; and 40.04 for periods 1-50 (around 17-24 percent higher than the BS case). This suggests that the practice of list pricing and discounting encourages tacit collusive behaviour. Price

[10] A t>82 and a p-value of 0.000 is found for all periods. Similar results are found for all subperiods considered. See the appendix for more details.

[11] A t>24 and a p-value of 0.000 is found for periods 25-50 on the differences in mean price between BS and LPS cases. Similar results are found for all subperiods considered. See the appendix for more details.

dispersion, measured by the standard deviation and coefficient of variation, is higher under list pricing with discounting, which may reflect that price coordination is hard to reach and noisy. When looking together at the mean and volatility of prices, the evidence suggests a stronger collusive behaviour in (later) periods 26-50 (higher prices and same coefficient of variation), which may reflect the fact that duopolists learn how to play or coordinate prices during the first 25 periods and thus reach higher prices over the remaining periods. That is why we would pay special attention to the analysis of periods 25-50 in what follows.

Table 1

Perfect competition	20	
Monopoly	55	

Periods		Average, median, and std. dev.			
		Baseline Symmetric	List Price Symmetric	Baseline Asymmetric	List Price Asymmetric
1-25	µ	32.985	38.547	36.623	37.489
	me	32.283	39.915	39.831	41.500
	σ	4.543	9.558	7.492	7.539
	cv	0.14	0.25	0.20	0.20
26-50	µ	33.727	41.550	39.673	39.867
	me	33.333	38.844	40.228	40.633
	σ	4.568	10.535	6.404	5.442
	cv	0.14	0.25	0.16	0.14
1-50	µ	33.356	40.049	38.148	38.678
	me	32.918	39.344	40.000	41.342
	σ	4.565	10.046	6.961	6.574
	cv	0.14	0.25	0.18	0.17

Figure 2 shows the average and median prices over all groups of players for each period. The horizontal lines indicate the Edgeworth and monopoly prices. Compared with the baseline, average prices under list pricing with discounting are relatively higher. Interestingly, price volatility is also higher under list pricing with discounting and, in addition to what was discussed before in table 1, it can be noticed that the volatility of prices changes over the first and second halves. This could reflect the difficulty in coordinating on prices. Furthermore, the third panel in figure 2 shows that the price dispersion is increasing during the first 25 periods, and decreasing after that, suggesting some learning.

Figure 3 provides the nonparametric estimates of the density and distributions of equilibrium market prices for the baseline as well as for the lisp price and discounting symmetric cases. The first panel shows that density of prices has a peak around 30 for the symmetric baseline case, while the peak is closer to 40 for the symmetric case with list pricing and discounting which whole density is shifted to the right. Putting together the two density functions and the list prices, it can be seen that, first, the list prices distribution stochastically dominates (in first order stochastics dominance -FOSD- sense) the other two distribution functions; and second the distribution of equilibrium prices under list pricing and discounting stochastically dominates the distribution of equilibrium prices in the symmetric baseline. Based on the distribution functions on the bottom panel, a formal first order stochastic dominance Kolmogorov Smirnov test was performed which confirms this finding. [12]

Figure 2

While we have already established that the practice of list pricing and discounting result in higher average prices, we want to now see whether this reflects in tacitly collusive behaviour of firms? For this we will now look at various measures of price coordination. We construct and evaluate two measures, Same and Duration, of coordination used in Harrington, Hernan and Kujal

[12] See appendix for more details. The largest difference between the distribution functions of baseline symmetric prices and list price symmetric case is 0.445. The approximate asymptotic p-value for this is 0.000, which is significant. The combined K-S involves a null hypothesis that the two distributions are equal. Since the approximate asymptotic p-value for the combined test is 0.000, the null hypothesis is rejected. Other tests, such as the Somers´s test, were performed with similar results to the Kolmogorov Smirnov test. Similar results are obtained when looking at FOSD of the distributions (BS vs announced LP, LP vs announced LP).

(2016). The Same index measures the number of periods for which sellers set the same price and the Duration index reports the longest number of consecutive periods for which sellers set identical prices. If sellers achieve high average prices and report high values of Same and Duration indexes, this would provide some evidence that they are colluding. If sellers achieve a high average price and low measures of coordination than it could either be that firms are not colluding or are colluding in a different manner that is not captured by these indices.

Figure 3

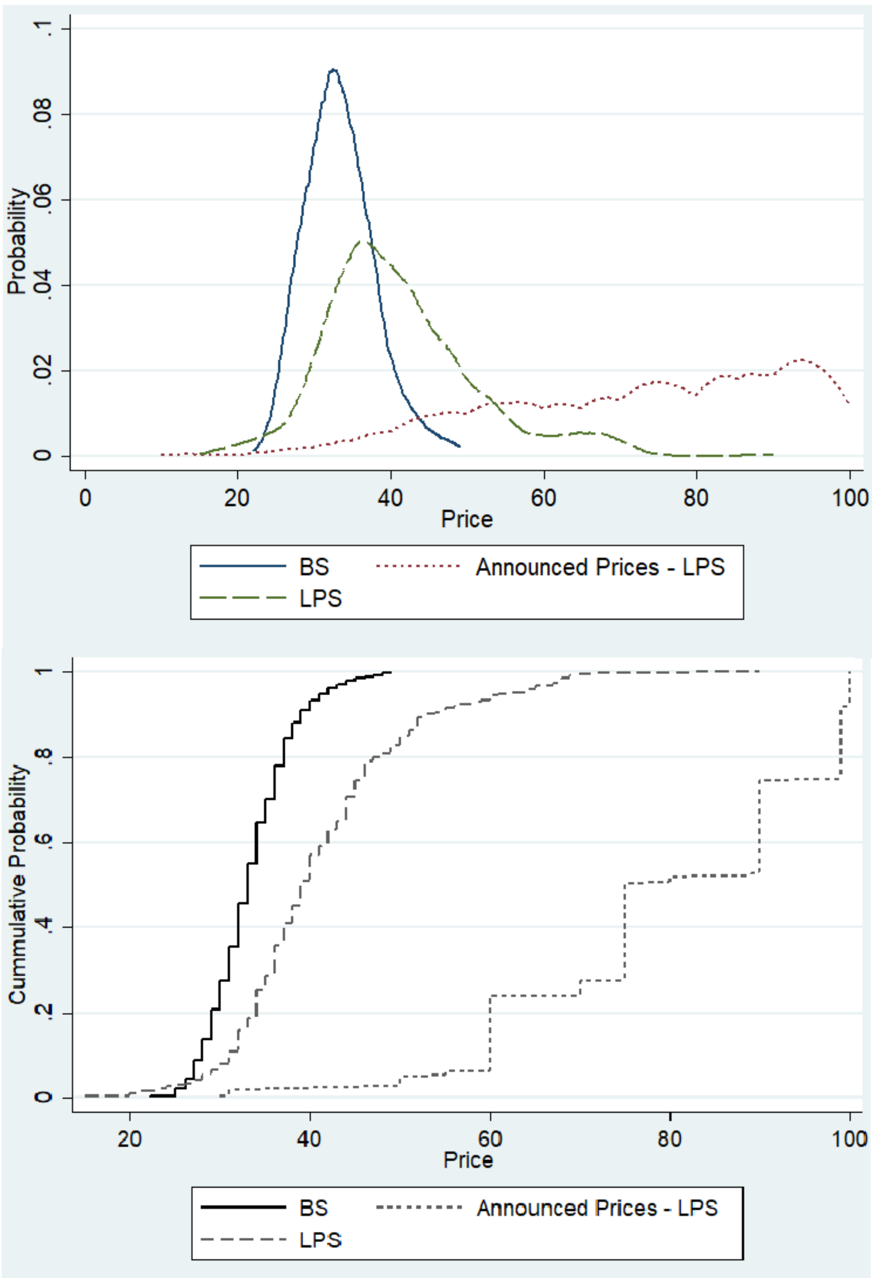


Table 2 contains information about the two indices of price coordination, Same and Duration. We provide information in two formats for both indices, i.e. the first column for each measure, i.e. *Same* and *Duration*, provides the index when the price is *exactly* the same. The next two columns provide the index when the prices differ in *no more than* 5 or 10%.

Looking at the Same index for the symmetric case (second column, Table 2) we see that, compared with the baseline, for both, periods 1-25 and 1-50, price coordination decreases under list price and discounting. For instance, for periods 1-25, the frequency of identical prices declines from 12.4% (3.1 out of 25 periods) to 5.2% (1.3 out of 25 periods). However, when making this comparison for periods 26-50, we observe an increase in the coordination frequency from 0.9 (3.6%) to 2 (8%) in table 2). This measure increases for the 5% measures, 4.6 to 5.0, while it decreases for the 10% measure (11.1 to 8). As mentioned before, during periods 26-50 agents have already learnt how to play this game, we think we should pay special attention to this result suggesting possible collusion.

Table 2

Baseline Symmetric Case						
	Number of periods with similar price			Duration of price coordination		
Periods	Same price	Diff.<=5%	Diff.<=10%	Same price	Diff.<=5%	Diff.<=10%
1-25	3.1	5.6	9.9	1.4	2.4	4.0
26-50	0.9	4.6	11.1	0.8	1.5	3.4
1-50	4.0	9.6	20.6	1.5	2.8	4.6

List Pricing Symmetric Case						
	Number of periods with similar price			Duration of price coordination		
Periods	Same price	Diff.<=5%	Diff.<=10%	Same price	Diff.<=5%	Diff.<=10%
1-25	1.3	2.6	6.5	1.0	1.4	2.7
26-50	2.0	5.0	8.8	1.0	2.1	2.7
1-50	3.3	7.6	15.0	1.3	2.2	3.1

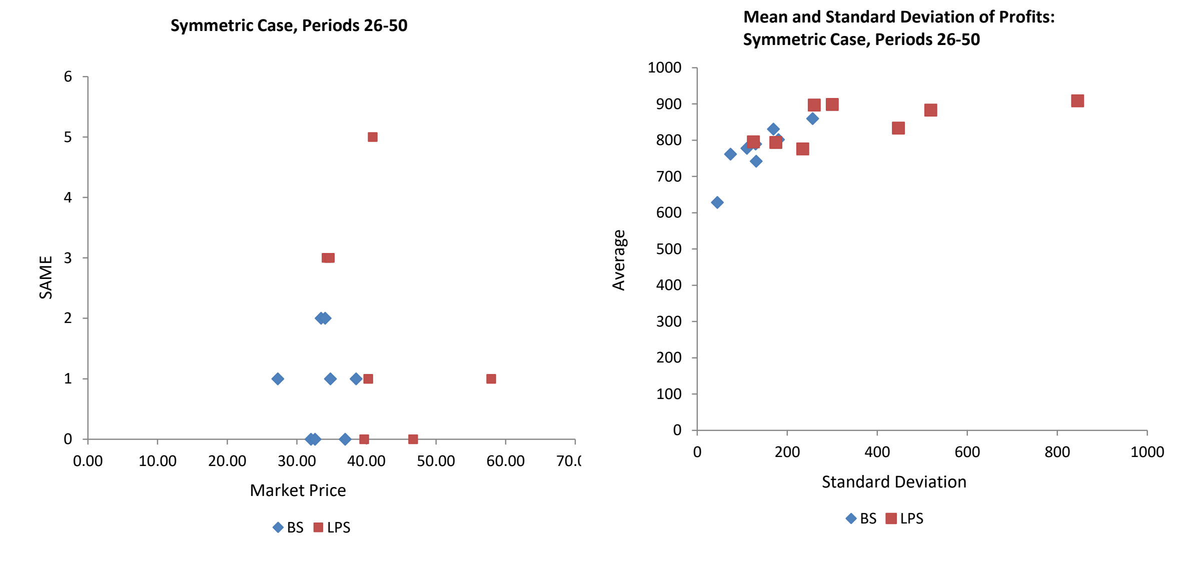
Now we look at Duration measure for price coordination. The fifth column (table 2) indicates the longest number of consecutive periods in which firms set *exactly the same* price decreases under list price and discounting with respect to the baseline case for periods 1-25 and 1-50. Looking at periods 1-50, the average maximal number of consecutive periods for which firms set the same price declines from 1.5 to 1.3 periods. The same tendency is observed when prices differ in no more than 5% and 10%, respectively. Again, there is no clear evidence that firms are colluding in this sense. However, the exception again appears when making this comparison for periods 26-50 when prices are exactly the same or do not differ in more than 5%. In this case we observe an increase in the duration from 0.8 to 1.0 and from 1.5 to 2.1, respectively, suggesting collusion.

Figure 4 plots the average market price versus the Same index in the first panel on the left, as well as the standard deviation of profits versus average profits in the panel on the right. In both cases, the indices correspond to the benchmark symmetric case and the list prices and discounting case for each group of matched duopolists. In the left panel, collusion would be associated with the northeast quadrant where prices and coordination measured by the Same index take higher values. We can see that, under list prices and discounting, prices as well as coordination tend to be higher relative to the benchmark baseline experiments (firms are setting higher prices for longer periods). In particular, there are three groups of firms showing higher average values of both indicators relative to the benchmark case.

In the right panel collusion would be associated with the northwest quadrant where industry profit would be high and correlated with low price dispersion. The results indicate that average industry profits increase for list price and discounting but there is no evidence of more stable profits relative to the baseline. Instead, list price and discounting is associated with higher and more variable profit.[13] In sum, we find evidence suggesting tacit collusion resulting in higher prices but, coordination is noisy and might be organized in a non-trivial way, for instance, taking turns to increase prices. Regardless, higher prices are observed under the list-pricing and discounting institution.

[13] In the appendix there is a sample of groups of players in which one can observe the announced list prices, and the discount prices.

Figure 4



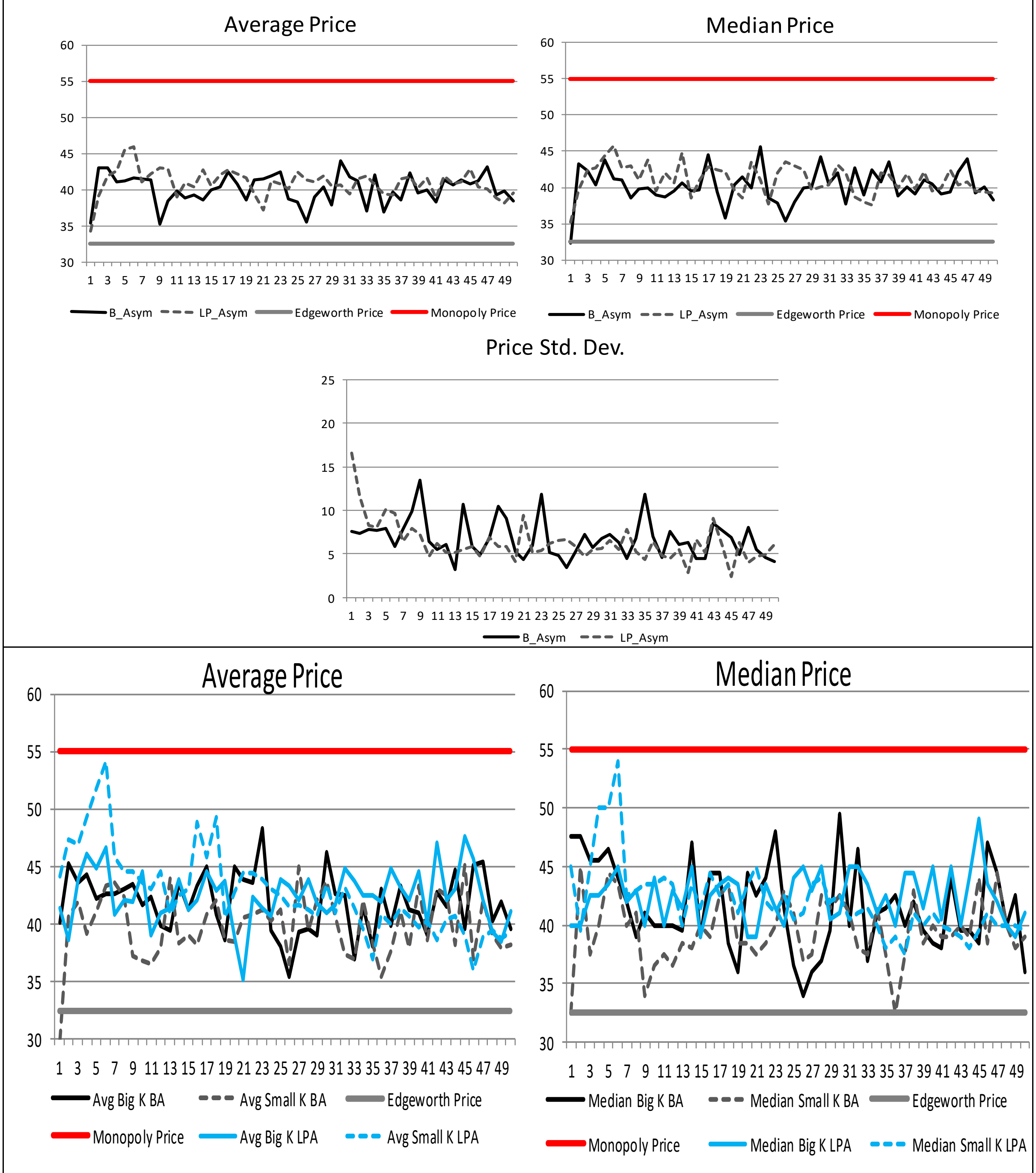
4.2 Asymmetric case: Baseline and List Price with Discounting

In this section we analyse the results for the asymmetric, baseline and list pricing with discounting, when firms are asymmetric in capacity constraints and symmetric in marginal costs. For the baseline-asymmetric case Table 1 reports the average market price and the median market price that are 41.1 and 40, respectively; for periods 1-25. This is an interesting result as it has been seen in experimental quantity setting markets that cost asymmetries result in more competitive behavior (Mason, Philips and Nowell, 1992), we, however, fins that under capacity asymmetry prices are significantly higher than the prices reported for the baseline symmetric case. The intuition from Fonseca and Normann (2008), when the capacities are simply redistributed, can be applied here for the baseline case. The largest firm can now unilaterally charge a higher price on the residual and this will consequently increase the average weighted static Nash equilibrium prices of the static game while reducing the minimum discount factor for collusion resulting in higher profits for all firms.

Additionally, these prices are only slightly lower than the prices reported when there is list pricing and discounting with asymmetric firms. The same pattern is present when analysing the prices for periods 26-50 as well as in periods 1-50. This result suggests that capacity asymmetries for homogenous goods may in fact result in more anti-competitive behavior.

In all cases equilibrium prices under LPA are higher than under baseline-asymmetric (BA). lying between the competitive price (20) and the monopoly price (55). Additionally, price dispersion, measured by the standard deviation and coefficient of variation, is lower only during the last twenty five periods (26-50) under list pricing with discounting, which may reflect price coordination. Additionally, from Figure 6 one can see that average and median prices tend to be higher for LPA but the difference decreases in period 26-50. It can also be noticed how price dispersion decreases in period 26-50 relative to period 1-25 when comparing list price with discounting and the benchmark case. This could, again, be an indicator of increased coordination.

Figure 6



It is also important that we compare the average prices for the small and large firm in the asymmetric list-pricing case. It could be that (as suggested by Garcia et al, 2012) the smaller firm chooses the Edgeworth price leaving the larger firm to monopoly price on the residual demand.

The lower panel of Figure 6 shows the evolution of prices by capacity constraints. One can see that, looking at average prices in the baseline case, the prices set by firms with higher capacity are in general higher than the prices set by firms with small capacity. The same happens when looking at the LPA treatment during periods 26-50 (once agents have learned how to play the game). Similar behaviour is present when we focus on median prices.

Figure 7 describes the density functions for both cases, the asymmetric baseline case (ba) and the asymmetric case with list pricing and discounting (lpa), which are quite similar. Also the announced list prices (annlp) are described, which stochastically dominates the other two density functions.

Figure 7

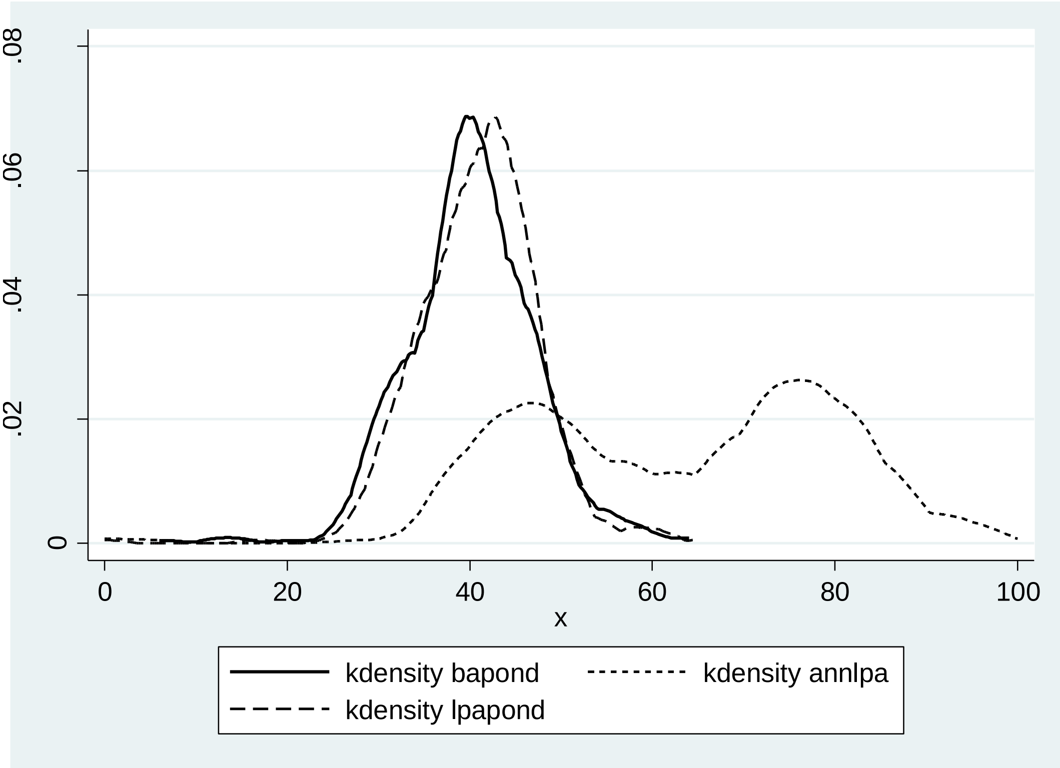


Figure 8 displays the density functions of prices for BA and LPA, discriminating firms by capacity constraints. It can be noticed that the prices set by firms with higher capacity tend to be higher than the prices of firms with small capacity. The same happens when looking at the case of list pricing and discounting, as explained when describing the graphs at the bottom of Figure 6. Here we show that the density function of prices of big firms tend to be shifted toward the right relative the ones for small firms.

Figure 8

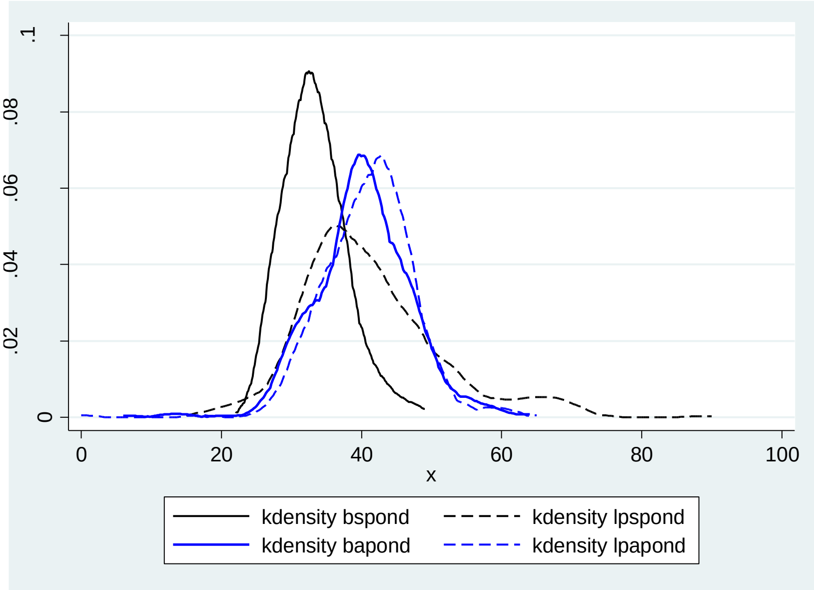


Table 3 indicates the measures of Same and Duration, as well as other variants of them, previously explained. The results indicate that for periods 1-25, the frequency of identical prices increases from 3.5% of periods to 4.3%. Similar pattern is present when comparing periods 26-50 and 1-50, in which the frequency of identical prices increases from 4% and 7.5% to 7% and 11%, respectively. The same occurs when firms set prices that differ in less than 5% and 10%

When looking at the Duration measure of price coordination, the evidence indicates that firms are coordinating prices. If we focus on periods 1-50, the average maximal number of consecutive periods for which firms set the same price goes from 1.4 to 1.6 periods, and similar pattern is found with respect to the other measures of Duration.

Table 3

Baseline Asymmetric Case

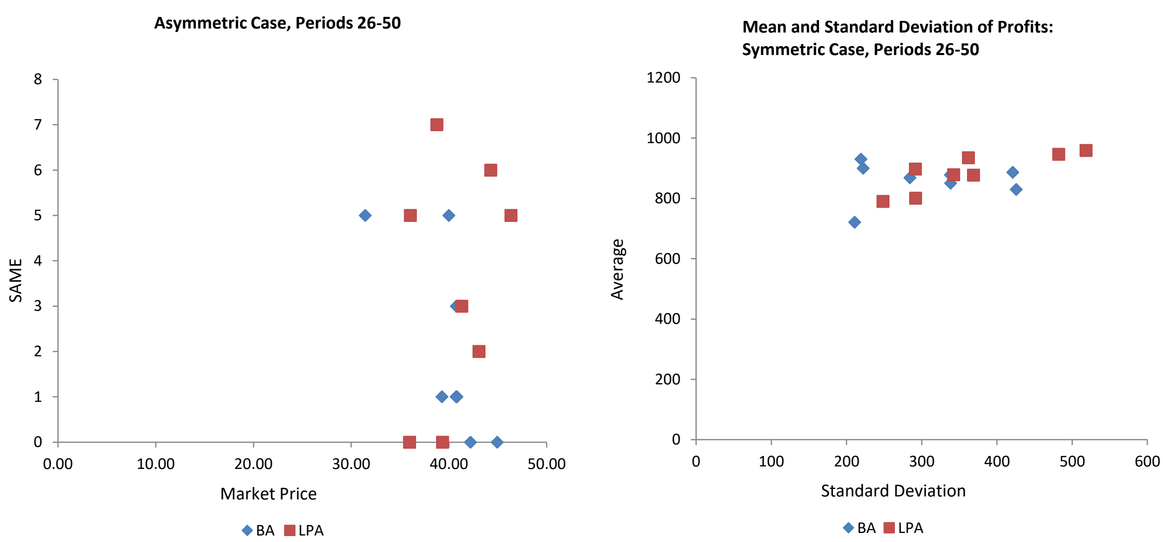
	Number of periods with similar price			Duration of price coordination		
Periods	Same price	Diff.<=5%	Diff.<=10%	Same price	Diff.<=5%	Diff.<=10%
1-25	1,8	3,9	6,6	0,9	2,1	3,1
26-50	2,0	3,9	7,8	0,9	1,5	2,5
1-50	3,8	7,5	13,9	1,4	2,6	4,1

List Pricing Asymmetric Case

	Number of periods with similar price			Duration of price coordination		
Periods	Same price	Diff.<=5%	Diff.<=10%	Same price	Diff.<=5%	Diff.<=10%
1-25	2,1	6,5	9,3	1,0	3,3	4,9
26-50	3,5	7,6	12,1	1,2	3,0	6,4
1-50	5,5	13,8	20,8	1,6	4,3	7,0

The two panels of figure 9 presents the average market price versus the Same, as well as the relationship between the standard deviation of profits and average profits, in both cases for the benchmark case and for the case with list prices with discounting for each group of agents. We can see that there are two groups of agents in the north east quadrant which, under list prices with discounting, document higher values for the average prices as well as for the coordination index Same relative to the benchmark case. This evidence is suggesting that firms are setting higher prices for longer periods, which indicates more coordination under list pricing and discounting with asymmetric firms. On the other hand, the second panel shows that the average profits are higher but more volatile under list pricing with discounting.

Figure 9



In sum, the evidence supporting collusion under list price with discounting in the duopoly asymmetric case is weaker than in the symmetric duopoly case.

5. Conclusion

The current paper develops and conducts experiments to study duopoly behavior in a Bertrand-Edgeworth multiperiod context with sequential stages of list pricing and discounting within each period. In this context the paper test whether list pricing and discounting is a competition enhancing practice or a (tacitly) collusive one. The results indicate evidence of collusion under list pricing and discounting with symmetric as well as with asymmetric firms relative to a baseline case without the discounting stage. It also suggests that pricing coordination is noisy and it is hard to find a clear dynamic mechanism by which firms synchronize pricing by analyzing the time series of price postings.

Appendix
Tests

Testing Baseline Symmetric Prices are different from competitive Price

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
B_Sym_~g	50	33.35597	.1628664	1.15164	33.02868	33.68327

```
    mean = mean(B_Sym_PPond_avg)                              t =  82.0057
Ho: mean = 20                              degrees of freedom =       49

    Ha: mean < 20              Ha: mean != 20              Ha: mean > 20
 Pr(T < t) = 1.0000        Pr(|T| > |t|) = 0.0000        Pr(T > t) = 0.0000
```

Testing LPS are highers than BS prices.

Paired t test

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
LP_Sym~g	25	41.1447	.6521573	3.260786	39.79871	42.49068
B_Sym_~g	25	33.72695	.2098181	1.049091	33.29391	34.16
diff	25	7.417741	.6413866	3.206933	6.093984	8.741498

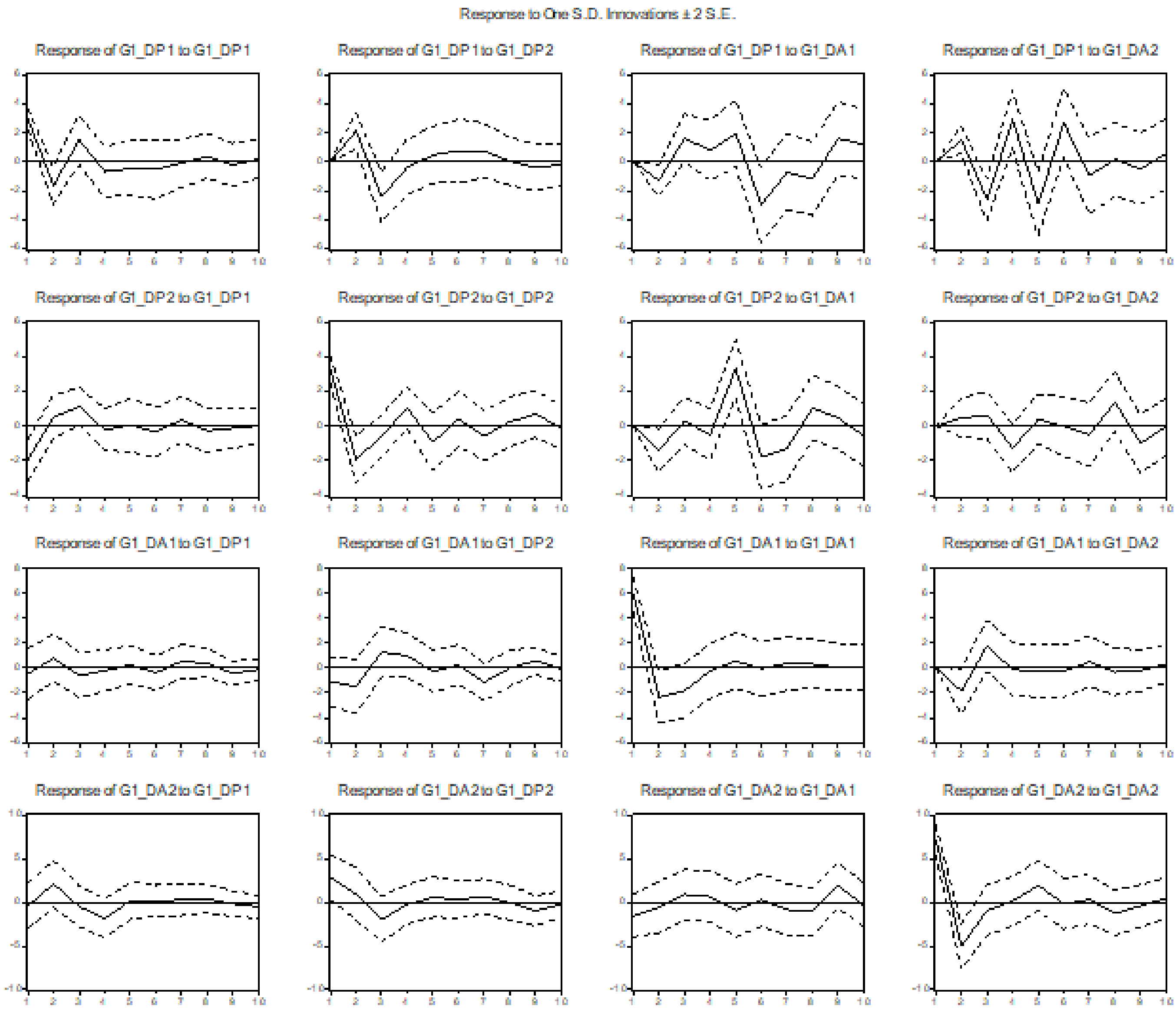
```
     mean(diff) = mean(LP_Sym_PPond_avg - B_Sym_PPond_avg)       t =  11.5652
 Ho: mean(diff) = 0                            degrees of freedom =       24

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

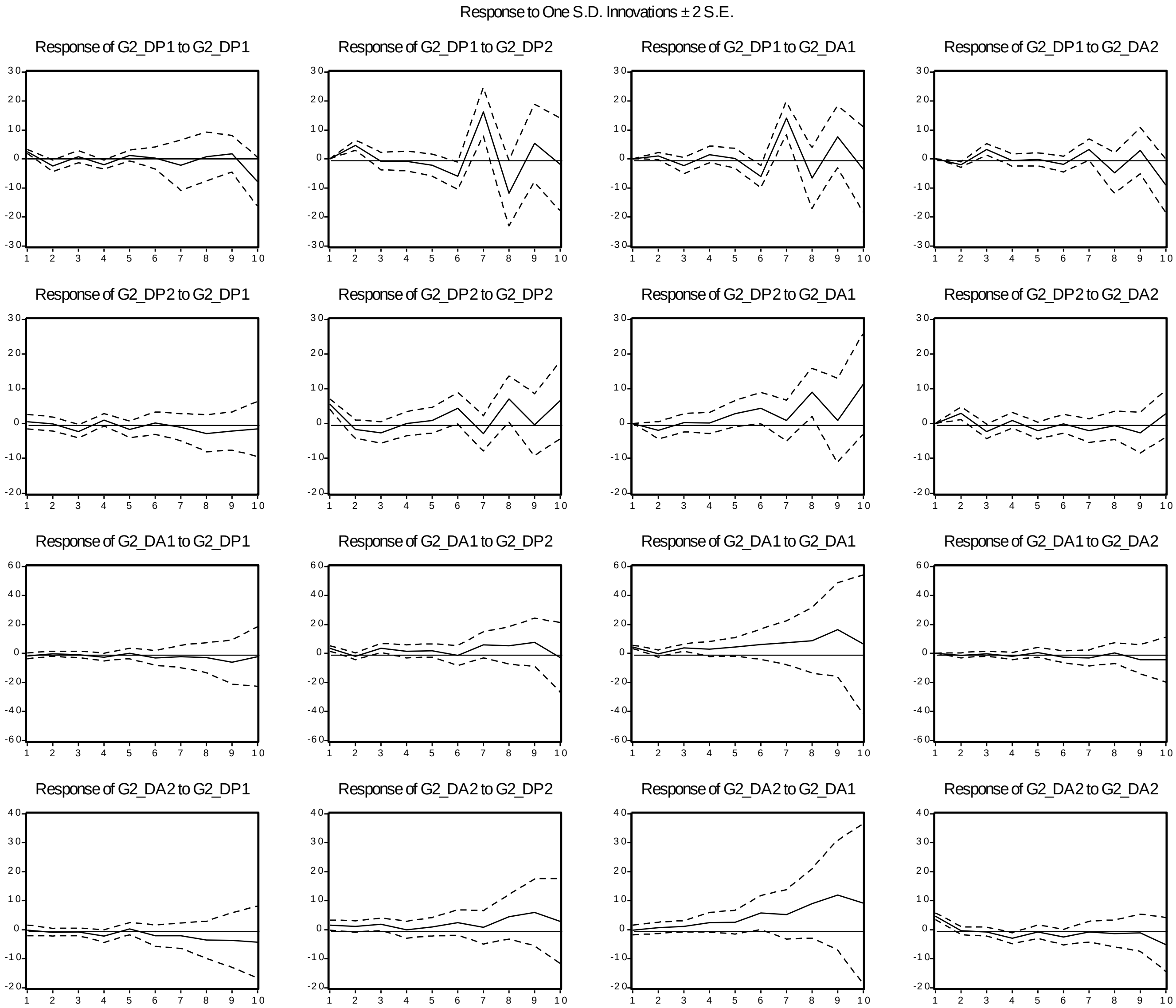
Testing First Order Stochastic Dominance between BS and LPS prices.

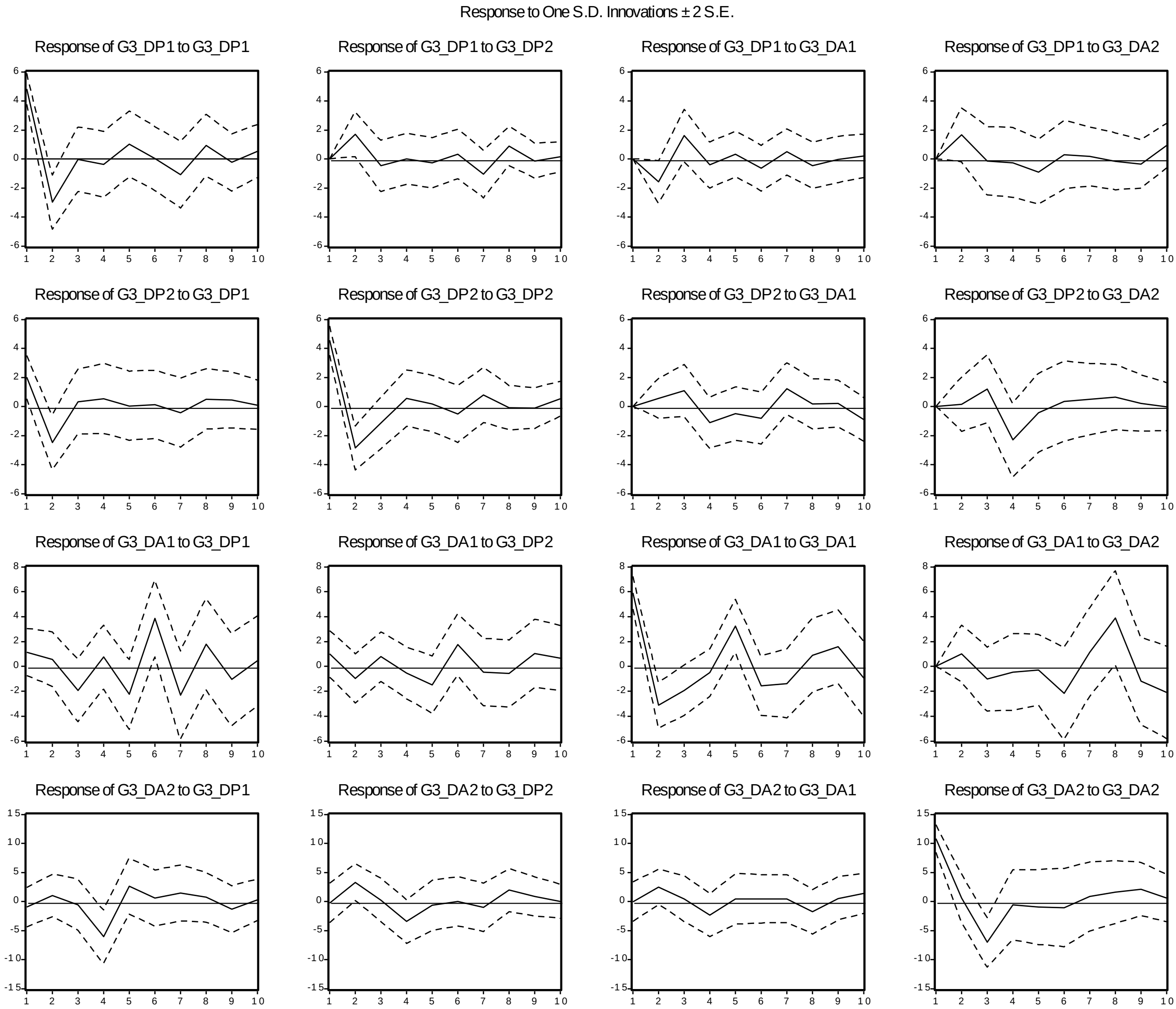
Two-sample Kolmogorov-Smirnov test for equality of distribution functions

Smaller group	D	P-value
bspond:	0.4325	0.000
lpspond:	-0.0225	0.817
Combined K-S:	0.4325	0.000

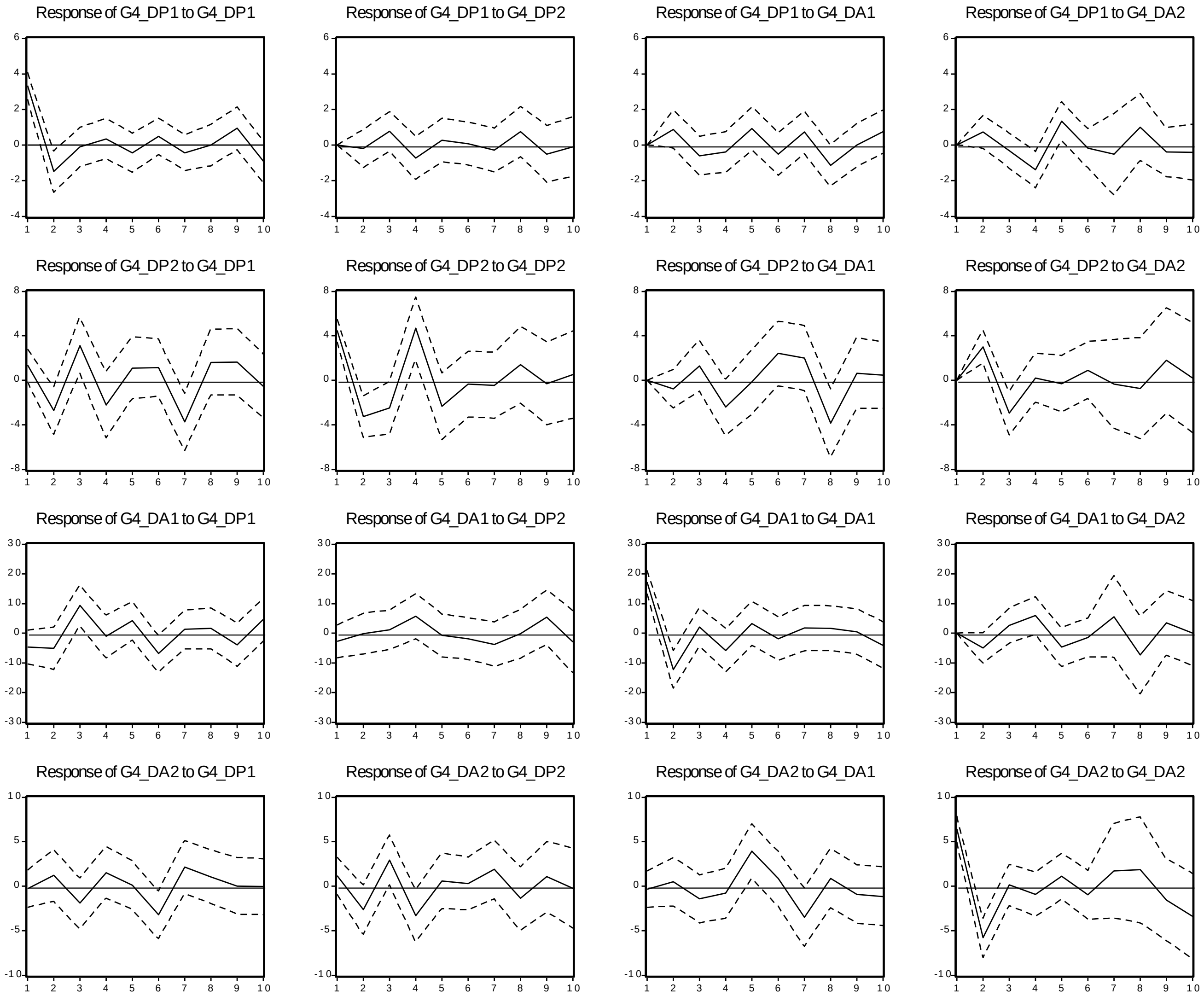
Impulse Response Functions

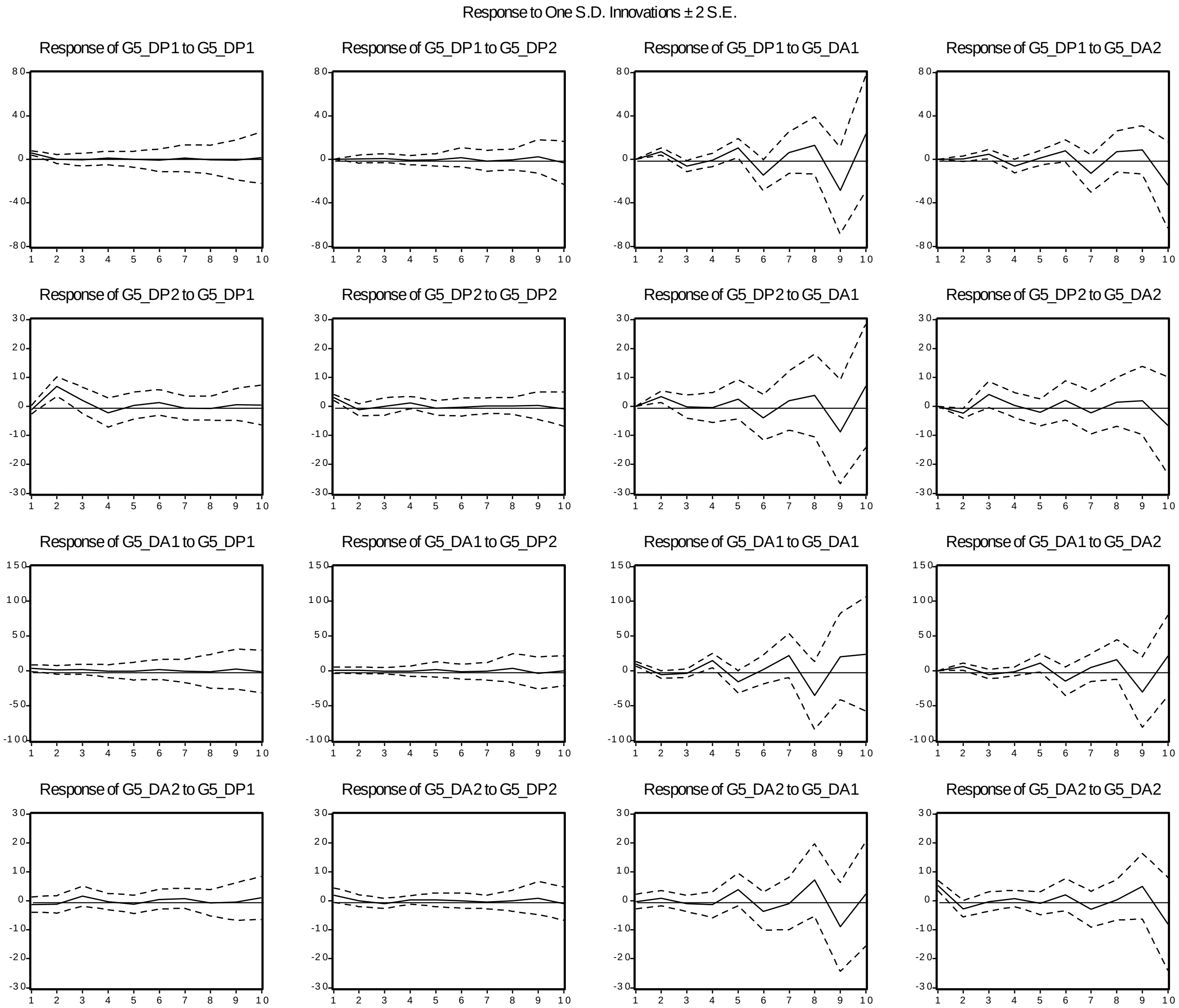



Response to One S.D. Innovations ± 2 S.E.
Response of G2_DP1 to G2_DP1
Response of G2_DP1 to G2_DP2
Response of G2_DP1 to G2_DA1
Response of G2_DP1 to G2_DA2
Response of G2_DP2 to G2_DP1
Response of G2_DP2 to G2_DP2
Response of G2_DP2 to G2_DA1
Response of G2_DP2 to G2_DA2
Response of G2_DA1 to G2_DP1
Response of G2_DA1 to G2_DP2
Response of G2_DA1 to G2_DA1
Response of G2_DA1 to G2_DA2
Response of G2_DA2 to G2_DP1
Response of G2_DA2 to G2_DP2
Response of G2_DA2 to G2_DA1
Response of G2_DA2 to G2_DA2


Response to One S.D. Innovations ± 2 S.E.
Response of G3_DP1 to G3_DP1
Response of G3_DP1 to G3_DP2
Response of G3_DP1 to G3_DA1
Response of G3_DP1 to G3_DA2
Response of G3_DP2 to G3_DP1
Response of G3_DP2 to G3_DP2
Response of G3_DP2 to G3_DA1
Response of G3_DP2 to G3_DA2
Response of G3_DA1 to G3_DP1
Response of G3_DA1 to G3_DP2
Response of G3_DA1 to G3_DA1
Response of G3_DA1 to G3_DA2
Response of G3_DA2 to G3_DP1
Response of G3_DA2 to G3_DP2
Response of G3_DA2 to G3_DA1
Response of G3_DA2 to G3_DA2

Response to One S.D. Innovations ± 2 S.E.




Response to One S.D. Innovations ± 2 S.E.
Response of G5_DP1 to G5_DP1
Response of G5_DP1 to G5_DP2
Response of G5_DP1 to G5_DA1
Response of G5_DP1 to G5_DA2
Response of G5_DP2 to G5_DP1
Response of G5_DP2 to G5_DP2
Response of G5_DP2 to G5_DA1
Response of G5_DP2 to G5_DA2
Response of G5_DA1 to G5_DP1
Response of G5_DA1 to G5_DP2
Response of G5_DA1 to G5_DA1
Response of G5_DA1 to G5_DA2
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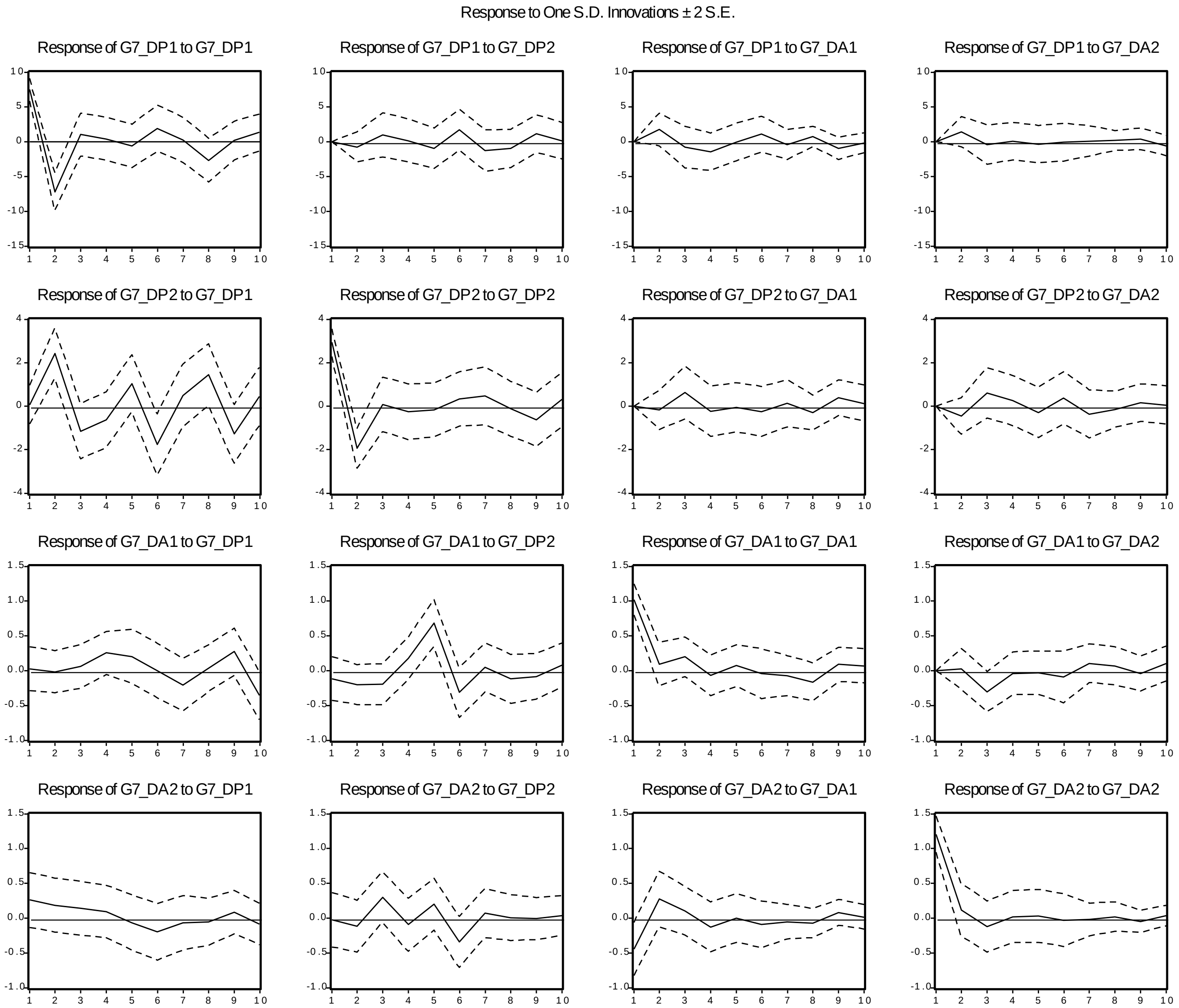
Response of G5_DA2 to G5_DA1
Response of G5_DA2 to G5_DA2


Response to One S.D. Innovations ± 2 S.E.
Response of G7_DP1 to G7_DP1
Response of G7_DP1 to G7_DP2
Response of G7_DP1 to G7_DA1
Response of G7_DP1 to G7_DA2
Response of G7_DP2 to G7_DP1
Response of G7_DP2 to G7_DP2
Response of G7_DP2 to G7_DA1
Response of G7_DP2 to G7_DA2
Response of G7_DA1 to G7_DP1
Response of G7_DA1 to G7_DP2
Response of G7_DA1 to G7_DA1
Response of G7_DA1 to G7_DA2
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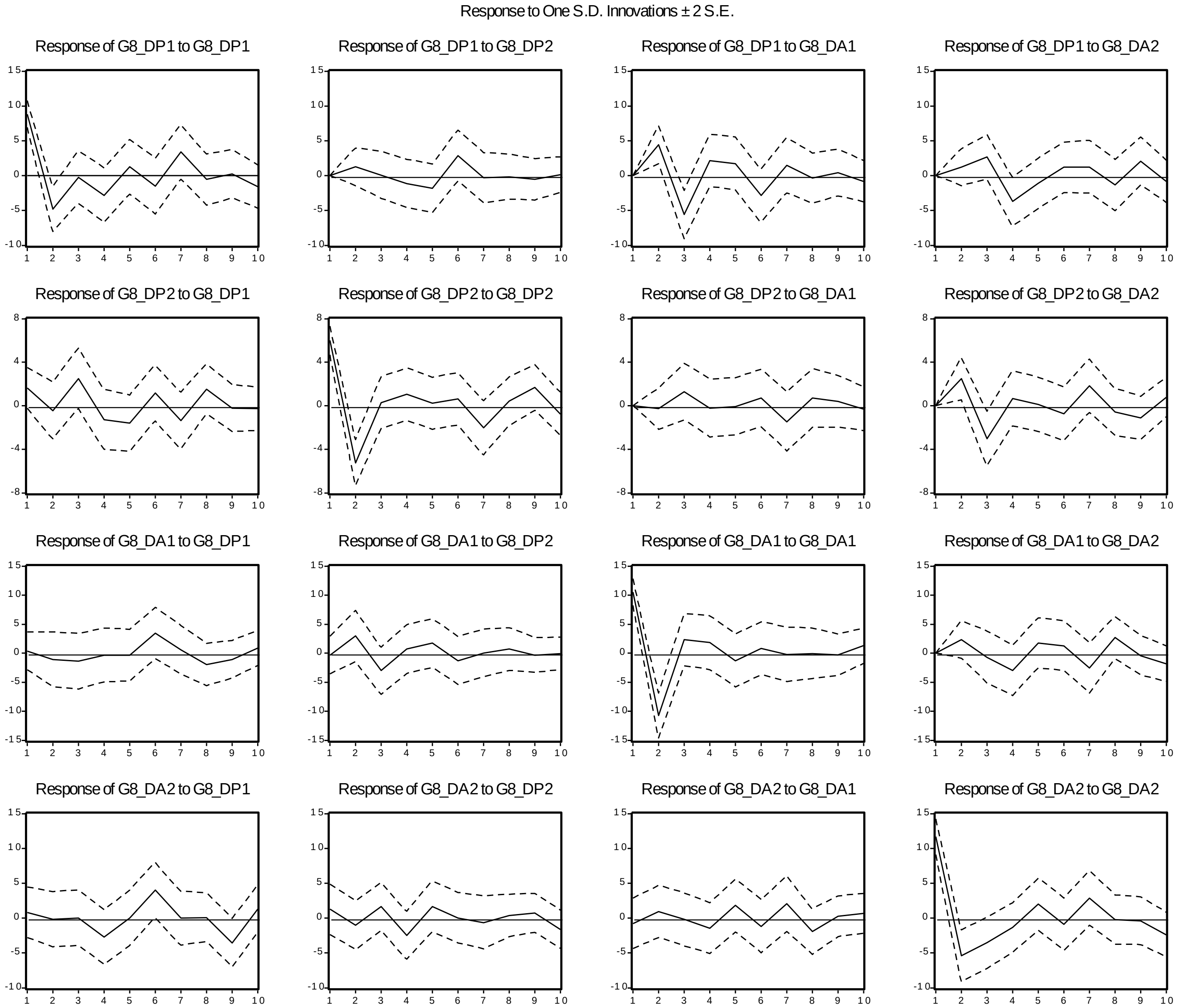
Response of G7_DA2 to G7_DA2


Response to One S.D. Innovations ± 2 S.E.
Response of G8_DP1 to G8_DP1
Response of G8_DP1 to G8_DP2
Response of G8_DP1 to G8_DA1
Response of G8_DP1 to G8_DA2
Response of G8_DP2 to G8_DP1
Response of G8_DP2 to G8_DP2
Response of G8_DP2 to G8_DA1
Response of G8_DP2 to G8_DA2
Response of G8_DA1 to G8_DP1
Response of G8_DA1 to G8_DP2
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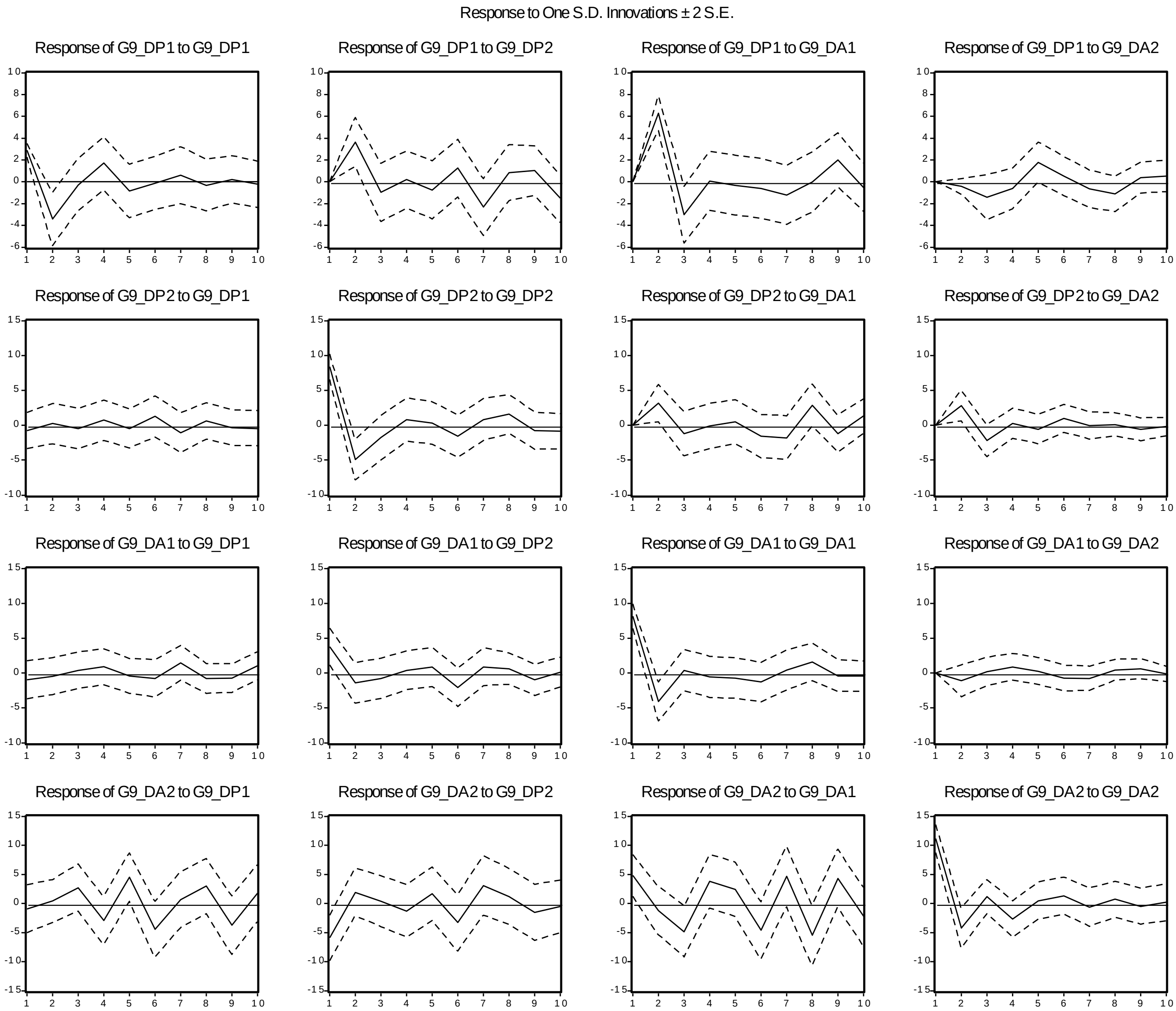
Response of G8_DA2 to G8_DA2


Response to One S.D. Innovations ± 2 S.E.
Response of G9_DP1 to G9_DP1
Response of G9_DP1 to G9_DP2
Response of G9_DP1 to G9_DA1
Response of G9_DP1 to G9_DA2
Response of G9_DP2 to G9_DP1
Response of G9_DP2 to G9_DP2
Response of G9_DP2 to G9_DA1
Response of G9_DP2 to G9_DA2
Response of G9_DA1 to G9_DP1
Response of G9_DA1 to G9_DP2
Response of G9_DA1 to G9_DA1
Response of G9_DA1 to G9_DA2
Response of G9_DA2 to G9_DP1
Response of G9_DA2 to G9_DP2
Response of G9_DA2 to G9_DA1
Response of G9_DA2 to G9_DA2

Variacnce Decomposition

Variance Decomposition of G1_DP1:

Period	S.E.	G1_DP1	G1_DP2	G1_DA1	G1_DA2
1	2.951241	100.0000	0.000000	0.000000	0.000000
2	4.457253	57.13035	22.94941	8.241205	11.67904
3	6.132267	36.35138	27.63343	11.43074	24.58445
4	6.883999	29.83127	22.24076	10.33920	37.58877
5	7.749431	23.88639	17.93490	14.51924	43.65947
6	8.772986	18.99719	14.73547	22.90081	43.36652
7	8.889193	18.51639	15.10929	22.97228	43.40204
8	8.975351	18.34713	14.82156	24.22238	42.60894
9	9.142347	17.73935	14.48542	26.41145	41.36378
10	9.243048	17.39648	14.20995	27.53000	40.86357

Variance Decomposition of G1_DP2:

Period	S.E.	G1_DP1	G1_DP2	G1_DA1	G1_DA2
1	3.809706	26.21085	73.78915	0.000000	0.000000
2	4.539545	19.78155	69.90600	9.287378	1.025066
3	4.762448	23.43605	65.05624	8.810358	2.697354
4	5.069202	20.86718	61.74720	8.746840	8.638784
5	6.132791	14.26542	44.42247	34.98702	6.325090
6	6.409011	13.34225	41.11484	39.74894	5.793973
7	6.589842	12.94522	39.63891	41.37558	6.040280
8	6.826200	12.20522	37.06167	40.94270	9.790409
9	6.951202	11.80534	36.72940	39.94971	11.51555
10	6.974909	11.72537	36.49317	40.34305	11.43842

Variance Decomposition of G2_DP1:

Period	S.E.	G2_DP1	G2_DP2	G2_DA1	G2_DA2
1	2.537408	100.0000	0.000000	0.000000	0.000000
2	6.230764	32.27160	55.17449	2.338774	10.21513
3	7.486241	23.43632	39.49066	11.22494	25.84808
4	7.967008	27.34765	35.94001	13.41103	23.30131
5	8.338498	26.78078	39.63284	12.25164	21.33474
6	12.08029	12.79658	42.88910	31.73487	12.57945
7	24.89330	3.832315	52.36944	39.19595	4.602293
8	28.73595	2.931476	56.05206	34.67345	6.343009
9	30.38215	2.960925	53.28991	37.19088	6.558284
10	32.91423	8.279663	45.76084	32.91181	13.04768

Variance Decomposition of G2_DP2:

Period	S.E.	G2_DP1	G2_DP2	G2_DA1	G2_DA2
1	5.582669	0.674292	99.32571	0.000000	0.000000
2	6.810946	0.506923	72.70685	8.481045	18.30518
3	8.011290	8.897814	63.40687	6.203830	21.49148
4	8.132487	10.25762	61.53288	6.063825	22.14567
5	9.046885	11.97745	50.66140	14.28198	23.07916
6	10.97088	8.150267	50.25719	25.88777	15.70477
7	11.61060	8.205853	50.88723	23.61626	17.29066
8	16.53285	7.098699	43.19871	41.06612	8.636473
9	16.91451	8.464215	41.31676	39.53082	10.68821
10	21.63331	5.706309	34.62324	51.46724	8.203210

Variance Decomposition of G3_DP1:

Period	S.E.	G3_DP1	G3_DP2	G3
1	4.830108	100.0000	0.000000	0.0
2	6.352850	79.82814	7.174116	6.1
3	6.572746	74.57831	7.215994	11.
4	6.601518	74.26003	7.153242	12.
5	6.755151	73.26498	6.995394	11.
6	6.799222	72.31914	7.147114	12.
7	6.984692	70.98471	9.015831	12.
8	7.120029	70.06661	10.21471	12.
9	7.134167	69.90950	10.21013	12.
10	7.218355	68.84172	10.01265	12.

Variance Decomposition of G3_DP2:

Period	S.E.	G3_DP1	G3_DP2	G3
1	4.967796	16.26921	83.73079	0.0
2	6.272466	25.75375	73.40803	0.7
3	6.590794	23.55990	69.54810	3.4
4	7.116634	20.77495	60.27752	5.4
5	7.150332	20.58238	59.78078	5.8
6	7.226375	20.18363	59.06616	7.0
7	7.399816	19.58964	57.44029	9.4
8	7.447315	19.80481	56.72732	9.3
9	7.466946	20.05269	56.45106	9.3
10	7.540762	19.68022	55.84480	10.

Variance Decomposition of G4_DP1:

Period	S.E.	G4_DP1	G4_DP2	G4_DA1	G4_DA2
1	3.329634	100.0000	0.000000	0.000000	0.000000
2	3.828059	90.79923	0.229815	5.319108	3.651843
3	3.966202	84.64888	4.065527	7.211982	4.073610
4	4.298846	72.72269	6.378264	6.968902	13.93014
5	4.630516	63.60669	5.860840	10.00388	20.52859
6	4.687887	63.16277	5.743170	10.94673	20.14733
7	4.798483	61.11456	5.819078	12.71890	20.34746
8	5.089079	54.33458	7.430875	16.25198	21.98257
9	5.215021	55.01687	7.994453	15.47695	21.51173
10	5.361362	54.83849	7.589749	16.65632	20.91544

Variance Decomposition of G4_DP2:

Period	S.E.	G4_DP1	G4_DP2	G4_DA1	G4_DA2
1	4.664448	8.434810	91.56519	0.000000	0.000000
2	7.044825	18.73257	61.77374	1.167256	18.32643
3	8.715472	25.11202	48.40716	2.990251	23.49057
4	10.41315	22.10385	53.95206	7.448441	16.49564
5	10.73589	21.85439	55.51005	7.025986	15.60957
6	11.10214	21.48500	52.01791	11.22417	15.27292
7	11.89804	28.63430	45.44646	12.54133	13.37791
8	12.70117	26.71597	41.07308	20.14145	12.06951
9	12.94849	27.32933	39.57100	19.61086	13.48881
10	12.97909	27.36859	39.54239	19.63912	13.44989

Variance Decomposition of G5_DP1:

Period	S.E.	G5_DP1	G5_DP2	G5_DA1	G5_DA2
1	5.857016	100.0000	0.000000	0.000000	0.000000
2	9.227080	40.32541	0.060878	59.22345	0.390261
3	12.17830	23.32120	0.620052	60.78533	15.27342
4	13.81128	18.90275	0.861309	47.44337	32.79256
5	17.34566	11.98995	0.615629	66.07115	21.32328
6	24.01727	6.409698	0.830759	70.88567	21.87387
7	28.05143	4.844369	0.904933	56.65154	37.59916
8	31.65731	3.813413	0.718782	60.75145	34.71636
9	43.55923	2.040664	0.713747	74.93388	22.31171
10	55.05754	1.346745	0.799248	65.34120	32.51281

Variance Decomposition of G5_DP2:

Period	S.E.	G5_DP1	G5_DP2	G5_DA1	G5_DA2
1	3.324287	13.47621	86.52379	0.000000	0.000000
2	8.717385	63.66097	14.49147	14.35825	7.489312
3	9.835924	54.48078	11.38422	11.31098	22.82402
4	10.17628	55.78153	12.02768	10.74388	21.44690
5	10.69262	50.57821	11.16501	15.03827	23.21850
6	11.64580	43.88379	9.465074	24.01853	22.63261
7	12.02030	41.42198	8.904035	25.10772	24.56626
8	12.70497	37.40609	7.981219	31.17929	23.43340
9	15.55557	25.12686	5.354639	52.29677	17.22173
10	18.33741	18.15124	4.102595	52.55185	25.19432

Variance Decomposition of G7_DP1:

Period	S.E.	G7_DP1	G7_DP2	G
1	7.513471	100.0000	0.000000	0.
2	10.66539	94.99565	0.508340	2.
3	10.79765	93.56684	1.367538	3.
4	10.90584	91.84784	1.361656	4.
5	10.96760	91.10399	2.083634	4.
6	11.31953	88.42545	4.265162	5.
7	11.40444	87.15726	5.508350	5.
8	11.77534	86.87345	5.847544	5.
9	11.87843	85.39461	6.677742	6.
10	11.97002	85.35352	6.587259	6.

Variance Decomposition of G7_DP2:

Period	S.E.	G7_DP1	G7_DP2	G
1	2.925385	0.052948	99.94705	0.
2	4.287658	31.96659	66.78288	0.
3	4.525660	35.20252	59.97354	2.
4	4.588890	36.09385	58.65904	2.
5	4.718840	39.01421	55.61051	2.
6	5.069394	45.94052	48.60762	2.
7	5.129863	45.78242	48.32021	2.
8	5.343670	49.59009	44.58695	2.
9	5.543875	51.32152	42.69236	2.
10	5.571592	51.43738	42.57968	2.

Variance Decomposition of G8_DP1:

Period	S.E.	G8_DP1	G8_DP2	G8_DA1	G8_DA2
1	8.844916	100.0000	0.000000	0.000000	0.000000
2	11.12464	81.74011	1.292749	15.80867	1.158477
3	12.73602	62.39808	0.991726	31.23310	5.377088
4	13.78388	57.49356	1.544890	29.08358	11.87797
5	14.11243	55.65134	3.142041	29.24877	11.95786
6	14.81060	51.57403	6.579574	30.31508	11.53131
7	15.31619	53.12833	6.194451	29.24901	11.42821
8	15.39187	52.74344	6.149867	29.02314	12.08356
9	15.55022	51.69750	6.139197	28.50778	13.65551
10	15.67536	51.89969	6.048553	28.33286	13.71890

Variance Decomposition of G8_DP2:

Period	S.E.	G8_DP1	G8_DP2	G8_DA1	G8_DA2
1	6.213338	6.893326	93.10667	0.000000	0.000000
2	8.518827	3.945788	87.34046	0.105446	8.608305
3	9.471601	10.14753	70.73453	1.884388	17.23355
4	9.638765	11.52200	69.49095	1.881070	17.10598
5	9.776492	13.92560	67.59741	1.832667	16.64433
6	9.917348	14.88697	66.09261	2.266214	16.75421
7	10.47709	15.02839	62.94206	3.980557	18.04899
8	10.63236	16.58497	61.27427	4.299548	17.84121
9	10.83018	16.02934	61.42980	4.262587	18.27827
10	10.89388	15.91069	61.20309	4.285975	18.60024

Variance Decomposition of G9_DP1:

Period	S.E.	G9_DP1	G9_DP2	G9_DA1	G9_DA2
1	2.891906	100.0000	0.000000	0.000000	0.000000
2	8.552446	27.47325	18.08778	54.20162	0.237353
3	9.241295	23.62722	16.58372	57.17399	2.615056
4	9.421252	26.06006	15.99987	55.01579	2.924281
5	9.660435	25.56539	15.81571	52.44116	6.177741
6	9.778042	24.97086	17.11845	51.59659	6.314103
7	10.16209	23.45936	21.05612	49.21062	6.273895
8	10.26389	23.09641	21.30163	48.24005	7.361908
9	10.51926	22.02844	21.24298	49.59358	7.135002
10	10.65530	21.51905	22.71553	48.56546	7.199963

Variance Decomposition of G9_DP2:

Period	S.E.	G9_DP1	G9_DP2	G9_DA1	G9_DA2
1	8.446307	0.797683	99.20232	0.000000	0.000000
2	10.65472	0.545973	83.69552	8.839815	6.918692
3	11.09863	0.708708	79.71846	9.306817	10.26601
4	11.15357	1.102396	79.44447	9.226564	10.22657
5	11.19360	1.276110	78.95513	9.341548	10.42721
6	11.52469	2.402721	76.40183	10.65320	10.54225
7	11.74429	3.179803	74.06316	12.60403	10.15300
8	12.20793	3.199634	70.23076	17.16716	9.402449
9	12.31819	3.230368	69.41090	17.86292	9.495820
10	12.43012	3.315882	68.64570	18.68629	9.352126

References

García Díaz, R. Hernán González and P. Kujal (2009): "List pricing and discounting in a Bertrand--Edgeworth duopoly", International Journal of Industrial Organization, 27 719-727.

Harrington JE, RH Gonzalez A and P Kujal (2016), "The relative efficacy of price announcements and express communication for collusion: Experimental findings", Journal of Economic Behavior & Organization 128, 251-264.

Holt, C., Scheffman, D. (1987): "Facilitating practices: the effects of advance notice and best price policies", Rand Journal of Economics 18, 187-197.

Huck, Normann and Oechssler (2004): "", Journal of Economic Behavior & Organization

List Price and Discount in a Stochastic Selling Process Z. Eddie Ning, Published Online:29 Jan 2021https://doi.org/10.1287/mksc.2020.1257

Charles F. Mason, Owen R. Phillips and Clifford Nowell (1992), "Duopoly Behavior in Asymmetric Markets: An Experimental Evaluation," The Review of Economics and Statistics, Vol. 74, No. 4 (Nov., 1992), pp. 662-670.

Scheffman, D.T., Coleman, M. (2003): "Quantitative Analyses of Potential Competitive Effects from A Merger", U.S. Department of Justice. http://www.usdoj.gov/atr/public/workshops/docs/202661.pdf.