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Evaluating a Price Change Limit Rule in a Simulated Exchange

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ABSTRACT

Intervention in commodity and capital asset markets is frequently justified by those who point to the reduction in price variability that might be achieved. In this paper a simulation of a centralized exchange for single commodity is made. Two modes of operation for the exchange are compared; one requires no intervention of any sort while the other imposes a limit in the period to period price change that may occur. It is found that imposing the price limit significantly changes three of the four market performance measures studied: price variance, fraction of all orders executed, average waiting time before execution, and daily dollar volume. Of these only waiting time is not significantly affected.

1. OVERVIEW AND REVIEW OF EARLIER WORK

The limitations of the capital asset pricing model of finance with its assumption of homogeneous expectations of the market participants are nowhere more evident than where an understanding of the mechanism of commodity and financial asset exchanges is sought. The existence of any transaction obviously implies the diversity of expectations.

On a more practical level diversity also exists in the design market mechanisms. In the U.S., on the NYSE in particular, and on other markets as well, actual trading on the floor of the exchange has been in the hands of "specialists" who trade for their own account, and by doing so are said to improve the performance of the market. Because of potential conflicts of interest, the specialist, at least in the U.S., is closely monitored. Even so, it has been suggested that his function might be automated with the twin benefits of the elimination of the need for oversight and of increased efficiency.

Three major performance criteria for any exchange dealing in commodities or financial assets are fairness, timeliness, and stability. By fairness is meant the objective of giving each incoming order the best available price as well as the more general goal of treating all market participants equally. Timeliness requires that orders be executed without undue delay. Stability refers to price stability; lack of price stability makes investors uncertain as to what price their market orders will receive and may reduce the volume of trading given investors basic tendency to avoid uncertainty.

It is clear that these three goals conflict given the unpredictable pattern of buy and sell orders entering the marketplace. Different stock markets are organized in different ways to deal with these uncertainties. One major dichotomy is that between markets in which designated market makers perform a price stabilization function and those where some other mechanism is employed. One alternative is to establish maximum alowable daily price changes, as is done on the Frankfurt and Tel Aviv exchanges or on some commodity exchanges. Another is to pool incoming buy and sell orders over time and then execute the orders at periodic intervals, in what is called a periodic call market.

The need for the designated market maker, or specialist as he is called in the U.S., is controversial. Does he actually improve price stability? Several studies have addressed various aspects of this question. Cohen, Maier, Ness, Okuda, Schwartz, and Whitcomb (1977) test a hypothesized relationship between returns variance and market thinness on the AMEX and on the NYSE and also on the Tokyo and the Rio de Janiero exchanges. The first two are specialist exchanges while the latter two are not. The authors found that returns variance and market value (volume) are inversely related on nonspecialist exchanges but not specialist exchanges and conclude that price stabilization, which they see as an externality, is desirable. Hakanson, Beja, and Kale (1985) also argue in favor of price setting, noting that securities markets do not permit limit orders which are conditional on the properties (eg. prices) of other assets.

Many researchers, such as Stigler, conclude no such outside stabilization is necessary or desirable. In thin markets, incentives exist for individual speculators to take on the role of specialist, and that to artificially stabilize the market delays price adjustments due to real and possibly dramatic changes in the economy and in so doing give those with inside information time to reap profits at the expense of others.

Even if price stabilization is desirable, how should it be accomplished? As noted earlier, the cost of overseeing the activities of the designated specialists who with their "limit order books" have exceptional information not available to others, may not be worth the price stabilization that results. Part of this cost might be the unfairness implicit in the asymetry of information. It is not surprising then that there has been considerable interest in automating the role of the specialist. Even with the recent advances in telecommunications and data processing at the fringes of the exchange, the heart of the exchange has been little affected.

Hakansson, Beja, and Kale (1985) use simulation examine the effect of several rules of trading on demand smoothing by an automated specialist. Many of these rules yielded similar results. Since our paper follows a similar approach it is worth describing their simulation model briefly. The model assumes there are a fixed number I of investors and S of securities. Trades occur at discrete time intervals which may be randomly spaced. All trades in a given security in the same time period occur at the same price. Prices, as in actual markets, are discrete. Short positions are possible. The state variables which change from period to period are represented by P_t and by (c_t,q_t), where c_t is the cash position and q_t is the S-vector of share holdings in the various securities by the automated specialist. The value v_t may also be calculated for each period.

2. ORDER GENERATION

In this model a single asset is traded by an unspecified number of market participants. The outlook is that of Garman (1976) in which the market agents are "treated as a statistical ensemble".

Specifically, the arrival of orders in the marketplace is modeled as a Poison process. Each order is one of the following types: market buy, market sell, limit buy, or limit sell. Short selling is not permitted. Once an order "arrives", its type is determined through the generation of a second random variable which is independent of the first. Thirdly the order size (the number of round lots) is randomly generated. For each limit order a limit price is randomly generated. The form of the probability distribution for this random variable is of a special type and its parameters may change over time and will be discussed in more detail later. For the moment it should be noted that the location parameter for this distribution is affected by previous transaction prices and by a fifth and final random variable representing "news" or random shocks from the external economic environment which are continually entering the marketplace.

Except for the order type and limit order price distributions noted above, all five random variables are independent of one another. It would be possible, and perhaps desirable, to specify other dependencies, but this was not attempted. In particular, there is evidence that a dependence between price and volume exists [See Crouch (1970), Tauchen and Pitts (1983), Epps (1975), Rogalski (1978), and in the futures markets Cornell (1981).]

The tendency to avoid uncertainty is a basic one among investors, and this risk aversion is built into the model by making the probability that an order is a market order inversely related to the spread (the difference between the highest current bid price and the lowest current ask price). The reason for doing this is that the transaction price typically jumps from from the highest bid to the lowest ask (or between successive highs and lows) and thus spread determines volatility. Thus when the spread is large the issuer of a market order is much more uncertain of the transaction price.

Each limit order must have an associated limit price. This price is the highest a participant is willing to pay or the least he is willing to accept, and thus depends among other things on the individual's expectations for the asset. In the case of a potential buyer, it is assumed the limit price will not exceed the most recent price, since if he were willing to pay that much he could achieve more certain execution with a market order. At the other extreme, it is assumed that there will be fewer and fewer bids at prices progressively farther below the market price. Realism and seriousness on the part of investors reinforced by the unwillingness of brokers to accept orders increasingly unlikely ever to be executed causes this reduction in the number of bids. The classical downward sloping demand curve (which would imply more bids at a lower limit order price) is simply not relevent, because i.) the investor is small relative to the market and perceives the market price as exogenously given and ii.) because he is serious, i.e. he has already decided to participate. A similar argument also applies to sellers.

Simple triangular distributions were used to model buy and sell limit order prices. The peak of each distribution is at the price one unit below and one unit above the perturbed market price for the bid and ask limit order price distributions respectively. The distributions are shown in Fig.1.

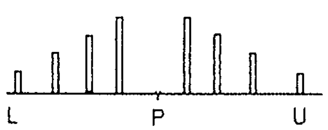

Fig. 1 Probability Density Function for Buy and Sell Limit Order Prices

It is assumed that no orders differing from the current perturbed market price by a certain percentage g will occur. In this study g=.05 was used. Thus L = .95P and U = 1.05P in Fig. 1.

The price about which the bid and ask limit price distributions are centered is the perturbed market price, that is, the most recent tranaction price to which a random shock has been added.

3. ORDER EXECUTION

After an order is generated at a random time, and its order type, the number of shares, and the limit price if it is a limit order determined as described in ther previous section, the order may either be immediately executed or entered in this study's simulation of the specialist's book to await matching against dome future incoming order. The data structure consists of two lists, actually matrices, one for buy orders called the bid list and the other for sell orders called the ask list. Each order on one of these lists has three components, the order size (the number of round lots), the limit order price, and the the time at which the order was entered. Although it is not important to this study, customers could be distinguished by the times recorded in the order book.

The procedure is as follows:

i.

If the order is to buy at the market, match it with the lowest asking price on the current list.

If the order is to sell at the market, match it with the highest bid price on the current list.

In either case cross out that row (all three components) in the ask list and record this price as the most recent transaction price.

In the event the bid list is empty for a sell order or the ask list is empty for a buy order, enter a sell or buy order respectively on the appropriate list at the most recent transaction price.

If the number shares of the new order does not match the number at the most favorable listed price, then the procedure described in the second paragraph of ii. must be followed.

ii.

If a limit order bid price of a new order is lower than the lowest listed ask price or if a limit order ask price is higher than the highest listed bid price, then order cannot be executed immediately and is added to the appropriate bid or ask list.

Otherwise, match the incoming order with the best price the current list to the extent there are shares available at this price. If not all shares are exhausted, simply reduce the number of shares for this entry on the list. If the number of ordered shares equals or exceeds those available at the most favorable listed price, remove this entry from the list, and, if it exceeds those available, repeat the process with the most favorable price on the now reduced listed. Continue in this way until all shares of the new order have been matched against listed shares as long as acceptably priced listed shares are available. If the order is not completed because the entire list is exhausted, then the balance of the order is entered on the opposing list.

As an example consider the following situation:

Bid List			Ask List		
Number	Price	Time	Number	Price	Time
4	200	2.3	3	202	1.8
3	198	2.7	2	203	1.9

and suppose a new order to buy 400 shares at the market. After the transaction, the book will appear as:

Bid List			Ask List		
Number	Price	Time	Number	Price	Time
4	200	2.3	1	203	1.9
3	198	2.7			

4. COMPUTATIONAL RESULTS

The basic experiment compares four measures of market performance or efficiency under two different sets of market rules. One set is the simple model without specialist or any other volatility tempering device. The other is a restriction on price movements from one period to the next. Any order which would result in a price change from the price at the end of the last period greater than some preassigned would be forbidden and such an order would be added to the bid or the ask list.

Ten separate and independent "days" of trading were modeled, each consisting of 240 periods. (One might imagine an exchange open just 4 hours per day with periods of 1 minute each or one open 24 hours a day with 6 minute periods, or some intermediate combination). Orders arrive throughout the day according to a Poisson distribution without regard to time period boundaries. The bid and ask lists are updated after each order arrives. Each day's trading was conducted under first the unrestricted rules and then under the price limit rule and performance measues were compared.

The four measures were fraction of total orders executed within the 240 period day, price variance, average waiting time from arrival to execution (taken over all executed orders), and total value of shares traded during the day. The non-parametric Mann-Whitney test was applied to each of these four measures. The results of these four tests when the price change limit was 6 were as follows:

Price variance:
The difference in price variances under the two rules is significant at .0113.

Fraction orders traded:
The difference in the fraction of orders traded is significant at .0022.

Average waiting time:
The difference in average waiting times is significant at .7337.

Total value:
The difference in total value of daily shares traded is significant at .0257.

Thus, except for waiting time, we can reject the null hypothesis that there is no difference in these measures at the $\alpha = .05$ level.

This experiment was repeated a second time with a more severe price change restriction of 4, and the significance levels corresponding to those above were as follows:

Price variance	.0004
Fraction orders traded:	.0002
Average waiting time:	.6232
Total value:	.0002

Even at the more restrictive limit there is no significant difference in average waiting times and in three days of the ten the average waiting time for the market without price change limits exceeded that for the market with the limit of 4.

In all 20 comparisons, imposition of the price change limit at either level, resulted in a reduction in the fraction of orders executed and also in a reduction in the dollar trading volume. In just one case, occurring when the higher, less restrictive, price limit was in effect, the price variance for price controlled market was higher than for the uncontrolled market.

The decrease in price variance is an objective to be sought and the milder price restriction reduced this from a range of 16.5 to 51.3 to a range of 11.4 to 28.8. The cost of this reduction in lost trading amounts to an average of daily difference of about $195,000 on a daily volume of roughly $2,500,000.

5. CONCLUSION

The imposition of a price change limit on a simulated exchange results in a significant decrease in trading volume, a decrease in the fraction of orders executed, and a decrease in price variance. The significance of these three decreases increases as the price limit is made more severe. No conclusion could be drawn about the average time an executed order must wait before it is executed.

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