The underlying structure of futures market depth

Joost M.E. Pennings*, W. Erno Kuiper

Frenkel ter Hofstede and Matthew T.G. Meulenberg

Wageningen University

Faculty of Economics

Department of Marketing-Futures Markets Research

Hollandseweg 1

6706 KN Wageningen

The Netherlands

Voice: 31-317-482205

Fax: 31-317-484361

E-Mail: joost.pennings@alg.menm.wau.nl

JEL: Classification: G10; G20

Number of characters per page: 185

Keywords: Market depth; Futures exchange

---

*Corresponding author

The underlying structure of futures market depth*

Abstract

The lack of sufficient market depth particularly in many newly initiated futures markets results in relatively high hedging costs, and this inhibits the growth of futures contract volume. In this article the underlying structure of futures market depth is analyzed, from which a two dimensional market depth measure is derived. Understanding the underlying structure provides the management of the exchange with a framework in which they can improve their market depth, and hedgers can obtain a better understanding of their market depth risk. The managerial implications of our findings are demonstrated empirically.

A key aspect of futures market performance is the degree of liquidity in the market (Cuny, 1993). The relation between market depth and futures contract success has been thoroughly investigated in the literature (Black, 1986). A futures market is considered liquid if traders and participants can buy or sell futures contracts quickly with little price effect as a consequence of their transactions. However, in thin markets, transactions of individual hedgers may have significant price effects and may therefore result in substantial 'transaction costs' (Thompson, Waller and Seibold, 1993).

* *The authors wish to thank the Amsterdam Agricultural Futures Exchange (ATA) for its financial support. We are indebted to the Clearing Corporation (NLKKAS), especially to Rolf Wevers, for invaluable data. Furthermore, we would like to thank the Board of Directors of the ATA, the management of the European Options Exchange and the participants of Chicago Board of Trade 1996 9th Annual European Futures Research Symposium, especially Paul Dawson of the City University Business School, for helpful comments on an earlier draft of this paper.*

These transaction costs are the premiums that traders are forced to pay or the discounts they are forced to accept in order to establish or close out futures positions (Ward and Behr, 1983). Although, to some extent, hedgers can take positions that offset each other, a futures market normally must create more market depth in the form of attracting additional traders if it is to become truly successful. In the literature four dimensions of liquidity are distinguished: immediacy, resiliency, width and depth (Berkman, 1993). Immediacy refers to how quickly trades of a given size can be done at a given cost. Resiliency refers to the responsiveness of new orders to price changes caused by temporary order flow imbalances initiated by uninformed traders. Width - often synonymous with liquidity - is represented by the bid-ask spread for a given number of futures. The bid-ask spread as a measure of width has some limitations. The price may change between the moment the market maker buys and sells, and the trader can earn much more or much less than the spread quoted at the time of the first transaction suggests. Hence, the trader faces costs due to changes in the bid-ask spread. Yet these costs are the essence of market liquidity (Grossman and Miller, 1988). Therefore, we examine the fourth dimension of liquidity: market depth. Market depth refers to the number of securities that can be traded at given bid and ask quotas (Berkman, 1993; Harris 1990). The concept of market depth represents a dimension of market liquidity that does not suffer from the limitations of the bid-ask spread as a dimension of liquidity (Kyle, 1985).

The contribution of our article is threefold. First, we investigate the price path caused by (temporary) order imbalances (i.e. insufficient market depth). Second, the article puts forward the underlying structure of market depth and proposes a measure of market depth. Third, we discuss the managerial implications of our model for the management of the futures exchange.

The article is organized as follows: Section I describes the concept of market depth. Section II gives a brief review of liquidity measures. Section III hypothesizes an underlying structure of market depth from which a market depth price path model is derived. The remainder of the article is concerned with the application of our model. Section IV describes the dataset and gives some data transformations. Section V presents an analysis of market depth for three selected futures contracts and subsequently the managerial implications for the management of the futures exchange are discussed. Results and main conclusions are summarized in Section VI.

I. Market depth in futures markets

Kyle (1985) defines market depth as the volume of unanticipated order flows able to move prices by one unit. Market depth risk is the risk the hedger faces of a sudden price fall or rise due to order imbalances. This risk seems important to systematic hedgers, particularly in thin markets. Sudden price changes can occur where both long and short hedges are concerned. If a relatively small market sell (buy) order arrives, the transaction price will be the bid (ask) price. For a relatively large market sell (buy) order, several transaction prices are possible, at lower and lower (higher and higher) prices, depending on the size of the order and the number of traders available. If the sell order is large, the price should keep falling to attract additional traders to take the other side of the order. Given a constant equilibrium price, in a deep market, relatively large market orders result in a smaller divergence of transaction prices from the underlying equilibrium price than in a thin market. According to Lippman and McCall (1986) the deepness of the market for a commodity increases with the frequency of offers. The generally known factors that determine market depth, and liquidity in general, include: the amount of trading activity[1] or the time rate of transactions during the trading period; the ratio of trading activity by speculators and scalpers to overall trading activity; equilibrium price variability; the size of a market order (transaction); expiration-month effect; and market structure[2] (Black, 1986; Thompson and Waller, 1988; Christie and Schultz, 1994; Chan and Lakonishok, 1995; Christie and Schultz, 1995). Hasbrouck and Schwartz (1988) report a relation between market depth and the trading strategies of market participants. Passive participants wait for the opposite side of their trade to arrive, but the active ones seek immediate transaction. Passive participants may avoid depth costs, whereas active ones generally incur depth costs. Some exchanges monitor temporary order imbalances, i.e., market depth risk, and slow down the trade process if these are present (Affleck-Graves, Hegde and Miller, 1994). For example, an order book official issues warning quotas when trade execution results in price changes that are larger than minimums predescribed by the exchange, and halt trading when order execution results in price changes that exceed exchange-mandated maximums (Lehmann and Modest, 1994).

II. Liquidity measures: a brief review

Previous research suggests measures of *liquidity* on the basis of indices, usually representing some weighting of trading activity (Working, 1960; Larson, 1961; Powers, 1979; Ward and Behr; 1974, Ward and Dasse; 1977). An important element in these measures is the proportion of hedging to speculative trading volumes. Several researchers (Roll, 1984; Gloston and Milgrom; 1985, Thompson and Waller; 1987, Stoll; 1989, Smith and Whaley; 1994) propose methods for an indirect estimation of liquidity costs. A liquidity cost proxy based on the estimated covariance of prices has been introduced by Roll (1984). Another accepted proxy for the bid-ask spread has been proposed by Thompson and Waller (1988), who suggest that the average absolute value of price changes is a direct measure of the average execution cost of trading in a contract. Smith and Whaley (1994) use a method of moments estimator to determine the bid-ask spread. This estimator uses all successive price change data, and assumes that observed futures transaction prices are equally likely to occur at bid and ask.

Market depth measures are rather scarce. Brorsen (1989) uses the standard deviation of the log price changes as a proxy for market depth. Lehmann and Modest (1994) study market depth by examining the adjustment of quotas to trades and the utilization of the chui kehai trading mechanism on the Tokyo Stock Exchange, where the chui kehai are warning quotas when a portion of the trade is executed at different prices. Utilizing the chui kehai trading mechanism can give an indication of market depth, but cannot be used to measure it. Other researchers such as Bessembinder and Seguin (1993) use both price volatility and open interest as a proxy for market depth.

These market depth measures implicitly assume a linear price path and for that reason provide limited insight into the underlying structure of market depth. In our view, the understanding of market depth can be improved if the market depth measure reveals the underlying price path caused by the thinness of the market. Market depth is usually analyzed by determining the slope dPF/dQ, where PF is the futures price and Q is the quantity traded. Presumably, the price path will not be linear, particularly not for large orders.

It is important to note that the price changes dPF in which we are interested are caused by order imbalances which, in turn, are caused by the characteristics of the futures exchange structure (i.e., the trading system and the rules of the exchange). There is a large volume of research in the literature (*e.g.* French and Roll, 1986; Fama, 1991; Stein, 1991; Foster and Viswanathan, 1993; Holden and Subrahmanyam, 1994; Oliver and Verrechia, 1994; Hiraki et al., 1995) on information, market efficiency and market liquidity. Information in these articles refers to information concerning fundamental economic factors (supply and demand factors of the underlying 'commodity' of the futures contract traded). Theoretically, we can split price changes in changes due to fundamental economic factors and changes due to the fact that there is a temporary order imbalance. In this study we will concentrate on the latter.

In the literature there are no measures that reflect the shape of the price path due to order imbalances, while it is this shape that provides insight into the underlying structure of market depth. Insight in the underlying structure of market depth is especially relevant to new commodity exchanges in Western and Eastern Europe because of the smaller scale of these exchanges (Kilcollin and Michael, 1993). Furthermore, the underlying structure of market depth is an important issue for the clearing houses with respect to the system of margining (Gemmill, 1994; Goldberg and Hachey, 1992). Insight into the underlying structure of market depth in combination with improvements in computer and telecommunications technology will lead to improvements in the structure of futures markets and financial institutions in general (Merton, 1995). For that reason we argue that it is necessary to determine the underlying process of market depth in order to compare futures markets with respect to market depth. With knowledge of this process we are able to distinguish different dimensions of market depth. Revealing these dimensions will help the management of the futures exchange in dealing with the problem of a lack of market depth.

III. Market depth model

We hypothesize that the price path arising from order imbalances can be characterized by an S-shaped curve. During the occurrence of such an S-curve the equilibrium price change is assumed to be constant.

It is assumed that the price path is downward-sloping in the case of a sell order imbalance and upward-sloping in the case of a buy order imbalance (Working, 1977; Kyle, 1985; Admati and Pfleiderer, 1988; Bessembinder and Seguin, 1993). The characteristic set of parameters describing the model can be interpreted as a measure of specific aspects of market depth.

We assume that the market depth price path consists of four phases, namely a sustainable phase, a lag adjustment phase, a restoring phase, and a recovery phase. Although we assume this four phase structure to hold for both upward- and downward-sloping price paths, we confine our discussion to a downward-sloping price path.

[INSERT FIGURE 1]

III.A. Sustainable Phase (I)

In the first phase the first contracts are sold at or near the bid price because of outstanding bids in brokers' order books. In this phase the already existing bids are

The market depth price path is caused by frictions in the market structure which includes the trading system and the rules of the exchange. The quality of the market information generated by the trading system regarding high price, low price, last price, size of last trade etc. is crucial for these frictions and consequently for the market depth price path (see Domowitz, 1993a,b) for a description of trading systems and their impact on market depth).

The S-shaped price path can only be identified ex post. Well-known theory with respect to market efficiency would suggest that the price would not adjust in a predictable way (Fama, 1991). However, at the moment that the price changes the participants are not able to identify whether the price movement is due to fundamental economic factors causing a change of the equilibrium price or due to a lack of market depth generated by market frictions caused by the trading system itself. Our findings have important managerial implication for the management of the futures exchange, both for the 'floor' and the clearing house. In Section V we will elaborate on these managerial implications.

A priori we do not assume that the downward-sloping S-shaped price path is exactly the reverse of the upward-sloping price path. It is possible, for example, that there are many stop-loss buy orders and hardly any stop-loss sell ones and vice versa, thus causing dissimilarity between upward-sloping and downward-sloping price paths (Chan and Lakonishok, 1993). Nor do we assume the length of the four phases to be equal. In a market that is not able to absorb orders near the equilibrium price, for example, Phase I will become rudimentary.

III.E. Mathematical Specification of the Model

In the mathematical model both sell and buy orders (downward- and upward-sloping price paths) are taken into account. An upward-sloping S-shaped path may well be approximated by a Gompertz curve, since this curve has a non-symmetrical S-shape and thus, does not impose certain restrictions on the length of the different phases previously described (Franses, 1994a). The Gompertz model is a growth curve and, therefore, can only be used to describe an upward-sloping price path. However, subtracting a downward-sloping price path from an appropriate constant may establish an upward-sloping price path which will cover the four phases. As a consequence, after transforming the data, the price path will always be upward-sloping. We can describe the transformed price series using the Gompertz model given by

$$(1) \qquad TPF_i = \alpha \exp(-\beta \exp(-\delta i))$$

where TPF_i is the transformed price of futures contract i ($i = 0,1,2,\ldots,n$), such that TPF_0 is equal to the minimum tick size, and α, β and δ are positive parameters. Since the price path is restricted to start in the minimum tick size, the parameter β is determined by α and the minimum tick size: $\beta = \ln(\alpha/r)$, where r denotes the minimum tick size. The parameters α and δ of the Gompertz model capture two dimensions of market depth. The first dimension, represented by α minus the minimum tick size, indicates how far the price rises (falls) as a consequence of a lack of market depth. The second dimension, presented by δ, has a one-to-one relation to the rate of adjustment, which, as we will show below, is equal to $[1 - \exp(-\delta)]$, cf. Chow (1967) and Franses (1994a,b). This rate of adjustment may be translated into a cost in terms of price risk; the futures price may change before actual order execution. The underlying structure of market depth can be visualized as shown in Figures 3 and 4.

Taking natural logarithms of (1) yields

$$(2) \qquad \ln(TPF_i) = \ln\alpha - \beta\exp(-\delta i)$$

A convenient representation of the Gompertz process is obtained by subtracting $\ln(TPF_{i-1})$ from (2) which after some rewriting using (1), gives,

$$(3) \qquad \mathrm{D}\ln(TPF_i) = [1 - \exp(-\delta)][\ln\alpha - \ln(TPF_{i-1})]$$

where D is the first order differencing filter defined by $\mathrm{D}z_i = z_i - z_{i-1}$. Equation (3) is of particular interest because it can be interpreted as a partial price adjustment model. In order to see this, note that $0 < [1 - \exp(-\delta)] < 1$. As a consequence, although α will always exceed TPF_i, $\ln(TPF_i)$ is rising toward $\ln\alpha$ at a constant rate of adjustment $[1 - \exp(-\delta)]$. For instance, if $[1 - \exp(-\delta)] = 0.1$, then it will take much more contracts to reach a certain price rise than in the situation where $[1 - \exp(-\delta)] = 0.5$, ceteris paribus. Similarly, if $\ln\alpha$ exceeds $\ln(TPF_i)$ by one percent of $\ln(TPF_i)$, then $\ln(TPF_i)$ will increase by $[1 - \exp(-\delta)] \times 100$ percent. We can additionally interpret $\exp(-\delta)$ as the elasticity of TPF_i with respect to TPF_{i-1}.

The model in (3) may be extended on two fronts. First, relation (3) is an approximation to the transformed price series. Hence, we add a disturbance term u_i to (3) under the assumption that $u_i \sim \text{IID}(0,\sigma^2 I_n)$. Second, notice that the price observations per futures contract cannot be described by a single curve like the one depicted in Figure 1, but by a sequence of such curves as in Figure 2, where an upward-sloping curve is always succeeded by a downward-sloping one and the other way round. As a consequence, our data series on the transformed price consists of a panel (not restricted to being balanced) of upward-sloping curves in chronological order. We may wish to allow the parameters to vary between really upward- and actually downward-sloping curves. To meet those ends, (3) is modified as in

$$\text{(4)} \qquad \text{Dln}(TPF_{ci}) = \pi_s - \tau_s \ln(TPF_{c,i-1}) + u_{ci}$$
$$\text{s.t.} \quad u \sim \text{IID}(0,\sigma^2 I_N)$$

where $\pi_s = [1 - \exp(-\delta_s)]\ln\alpha_s$, $\tau_s = [1 - \exp(-\delta_s)]$, $i = 0,1,\ldots,n_c$ with $c = 1,\ldots,H$ and s is an index for actually upward- ($s=1$) and downward-sloping ($s=2$) curves. H denotes the number of curves that form the graph of the futures price as in Figure 1. Notice that our dataset on TPF_{ci} consists of $N = \Sigma_{j=1}{}^{H}\, n_j$ observations. In the next section more details are given on how we obtain these observations.

III.F. Estimation of the model

In our theoretical model we assume that during the occurrence of an S-shaped price path, the equilibrium price is constant and hence that the S-shaped price path is solely attributed to temporary order imbalances. However, actual price changes in the futures market result from both temporary order imbalances and from supply and demand factors of the underlying commodity of the futures contract. As a result estimation of the model on the basis of real futures market data might invalidate the assumption of a constant equilibrium price during every separate S-shaped price path. This problem becomes less relevant as the S-curve, due to temporary imbalances, takes place in a shorter period of time. In our case we dispose of transaction specific data and S-shaped price paths occur in a very short period of time, say within a matter of minutes. Since the effect of fundamental economic factors occurs over a much longer period of time than a few minutes, we might expect that during such a downward-sloping or upward-sloping price path the price change due to fundamental economic factors i.e. the change of the equilibrium price is negligible compared to the price change due to order imbalances.

[INSERT FIGURE 2]

After identifying the individual price paths, we subtract the observations of each downward-sloping price path from the price at which the curve started, such that all curves become upward sloping. In order to eliminate the general price level effect, we shift the curves downward, such that each curve starts at the minimum tick size (i.e. each S-curve, as displayed in the window of Figure 2, is shifted downward to the minimum tick size). In doing so we also correct for differences in equilibrium price between S-curves.

IV. Data

In order to illustrate the usefulness of our model, we applied it to data from the Amsterdam Agricultural Futures Exchange (ATA). This exchange is one of the largest agricultural futures exchanges in Europe. The trading system employed by the ATA is the open outcry system. There are no scalpers on the trading floor and all orders enter the trading floor via brokers. Brokers are only allowed to trade by order of a customer. There is no central order book on the ATA. The broker has only insight into his/her own order book. There is no information on the order book of other brokers. The customer (hedger or speculator) has no information on outstanding orders.

Potatoes and hogs are traded on the ATA. The potato futures contract is a relatively successful one in the sense that the volume generated (about 200,000 contracts annually) is large relative to competitive potato contracts elsewhere in Europe (such as the potato futures traded on the London Commodity Exchange and on the Marché à Terme International de France). The annual volume is small, however, when compared with agricultural futures traded in the United States. Hogs futures are not successful as far as their volume (about 30,000 contracts annually) is concerned.

We use real-time transaction-specific data for three futures contracts: potato contract delivery April 1995, and hog contract deliveries August and September 1995. From the data it is not clear where the exact split between an increasing and decreasing price path should be imposed when two or more contracts in between are traded at the same price. Therefore, to determine the split we apply the following procedure: for an odd number of contracts traded at the same price we use the middle contract, and for an even number of constant contracts we employ a random assignment with equal probabilities.

V. Empirical results

In this section we present parameter estimates that are obtained by applying ordinary least squares to (4). From these estimates and the fact that $TPF_0 = \alpha\exp(-\beta)$ equals the known minimum tick size, we can simply derive the parameter estimates of the characteristic Gompertz curves. In the case of potatoes, the minimum tick size is equal to 0.10 Dutch guilders and for hogs it is some 0.005 Dutch guilders.

The regression results for the potato futures contracts are presented in Table 1. In Table 4 we present the companion parameter estimates of the characteristic Gompertz curves to be discussed later on in this section. From Table 1 we observe that the estimates of the rate of adjustment parameter are equal to 0.051 and 0.059. Note that these estimates lie within the (0-1) interval, which is in accordance with our model. The values of the corresponding t statistics are high, and are also highly significant when compared with the percentiles that have to be taken into consideration in the context of Dickey-Fuller tests (Stewart, 1991; Fuller, 1976). The Durbin-Watson statistic does not indicate any misspecification. In spite of its low value, the R^2 is significantly different from zero, as indicated by the F statistic. The intercept of actual downward-sloping curves is, however, not significant. Nevertheless, according to Table 4 this does not lead to the insignificance of the characteristic Gompertz curve parameters. To see whether one single market depth path for both upward- and downward-sloping price paths of potatoes suffices, we test the hypothesis H_0: $\{\pi_1 = \pi_2 = \pi$ and $\tau_1 = \tau_2 = \tau\}$. H_0 is rejected. Therefore, the market depth for potato futures contracts, delivery April 1995, significantly differs between periods of price rise and price fall.

Table 1. Regression Results for Potato Futures Delivery April 1995

Coefficient	Estimate	Standard error	t-value	p-value
π_1	0.016	0.002	6.621	0.000
π_2	0.001	0.003	0.253	0.800
τ_1	0.051	0.002	31.805	0.000
τ_2	0.059	0.003	29.992	0.000

Degrees of freedom 46786, from 46790 observations

R^2	0.099	Probability of F	0.000
F(4,46786)	1283	Durbin-Watson statistic	1.914

Table 2 presents the regression results for the hog futures contract, delivery August 1995. Since the hypothesis H_0 cannot be rejected, the market depth for hog futures, delivery August 1995, is characterized by a single Gompertz curve, the parameter estimates of which are to be found in Table 4. Compared with Table 1, the statistics in Table 2 lead to similar conclusions with respect to the performance of the regression.

Table 2. Regression results for hogs futures delivery August 1995

Coefficient	Estimate	Standard error	t-value	p-value
π	-0.478	0.035	-13.813	0.000
τ	0.147	0.008	18.646	0.000

Degrees of freedom 2739, from 2741 observations

R^2	0.249	Probability of F	0.000
F(2,2739)	454	Durbin-Watson statistic	1.811

Table 3 shows the estimates regarding the market for hog futures contracts, delivery September 1995. The results are quite similar to those in Table 2. Again, we cannot reject H_0. The parameter estimates of the characteristic Gompertz curve that can be derived from the parameter estimates in Table 3 are presented in Table 4.

Table 3. Regression results for hogs futures delivery September 1995

Coefficient	Estimate	Standard error	t-value	p-value
π	-0.339	0.032	-10.581	0.000
τ	0.108	0.007	14.750	0.000

Degrees of freedom 2314, from 2316 observations

R^2	0.200	Probability of F	0.000
F(2,2314)	288	Durbin-Watson statistic	1.855

Table 4. Estimates of the characteristic parameters describing the underlying dimensions of market depth

markets	slope of actual curves	parameter estimates characteristic Gompertz curve[1]	
		α	δ
Potatoes futures contracts, delivery April 1995	negative	1.013 (0.003)	0.060 (0.002)
	positive	1.374 (0.012)	0.053 (0.002)
Hogs futures contracts, delivery August 1995	both negative and positive	0.039 (0.008)	0.159 (0.007)
Hogs futures contracts, delivery September 1995	both negative and positive	0.044 (0.011)	0.115 (0.007)

[1] standard errors in parentheses

We will discuss the empirical results and illustrate how the management of the exchange can use this information to improve the performance of the futures exchange with regard to its market depth. For this purpose, we draw the characteristic Gompertz curves for the upward-sloping and downward-sloping potato futures price path (see Figure 3) and for the hogs futures price paths (see Figure 4), using the parameter estimates in Table 4. In each of the two figures both dimensions of market depth are visualized simultaneously. Several conclusions can be drawn from this.

[INSERT FIGURES 3 AND 4]

The upward- and downward-sloping Gompertz curves for *potato* futures have dissimilar shapes. The distance - indicating how far the price falls or rises due to order imbalances - is quite large compared with the general price level. This might be due to the absence of scalpers. In order to improve the absorption capacity, the ATA might consider allowing scalpers on the floor. The rate of price change (dimension 2) is higher for the upward-sloping price path than for the downward-sloping price path. This can be explained by the fact that there are differences between the number of stop-loss buy and stop-loss sell orders. Since the curves do not intersect, as displayed in Figure 3, we may conclude that the futures market is deeper in the case of a sell order imbalance than where there is a buy order imbalance. The problem of the high rate of (adverse) price changes at the ATA might be solved by implementing a mechanism for slowing down the trade process if order imbalances do occur and to improve market depth by reporting these. Also the order book information can be improved. At the ATA the order books of the different brokers are not linked and the customer has no information with regard to outstanding orders. An order book mechanism that allows potential participants to view real-time limit orders, displaying the desired prices and quantities at which participants would like to trade, will improve the rate of adjustment and the distance between the lower and upper bounds.

The upward- and downward-sloping Gompertz curves are similar for both *hogs* deliveries. The main difference between the two hogs futures with respect to market depth is caused by dimension 2, the rate of price change. This dimension prevails more for hog delivery in August than for hog delivery in September. From Figure 4 we observe that the price paths intersect, indicating that for relative small orders September delivery is deeper than August, whereas for large orders August delivery is deeper.

VI. Conclusions and further research

In contrast to the existing market depth measures we conjecture that the market price depth path has an S-shape in which four phases can be distinguished: the sustainable price phase, the lag adjustment phase, the restoring phase and the recovery phase. The S-shaped price path may well be approximated by the Gompertz curve, which allows for a non-symmetrical S-shape and hence, does not impose certain restrictions on the length of the different phases. The two parameters of our model represent two dimensions of market depth. The first dimension represents the distance between the upper and lower bounds, i.e. indicates how far the price falls (rises) due to a lack of market depth. The second dimension indicates the rate at which price falls or rises. Our market depth measure has convenient characteristics. First, it provides insight into the underlying structure of market depth and the management of the futures exchange and gives guidelines for improving market depth. Second, our measure can be used to compare competitive futures contracts. Third, the market depth model can simply be estimated. Furthermore, since our measure can be presented in a graphical way, it is relatively easy to interpret.

We applied our model to the potato and hogs futures traded on the Amsterdam Agricultural Futures Exchange. We found that both the distance between the upper and lower bounds of the price path and the rate of the price change is high, indicating a lack of market depth. The current trading system - no scalpers and no central order book information - contributes to this situation. Redesigning the trading system in order to lower the distance between the upper and lower bounds of the price path and the rate of the price change is recommended.

When interpreting the results, it is important to be aware of the following factors. First, as we have indicated, our model requires transaction-specific data. Transaction-specific data enable us to identify individual downward-sloping price paths and individual upward-sloping price paths. We shift the individual upward- and downward-sloping price paths, such that each price path starts at the minimum tick size. This means that the price path, as displayed in the window of Figure 1, is shifted downward to the minimum tick size in order to eliminate the price level effect (trend) caused by fundamental economic factors. Furthermore, we expect that during such a downward-sloping price path or upward-sloping price path, which takes place within a few minutes, price change due to fundamental economic factors is negligible compared to the price change due to order imbalances i.e. we may expect that during such a short period of time the equilibrium price does not change.

Second, our research is restricted to one futures trading system. In order to draw conclusions with respect to the relation between the two distinguished market depth dimensions and the futures market structure, other futures trading systems should be incorporated into the analysis. Measuring the market depth dimensions for different kinds of trading systems would provide more information regarding the relationships between the market depth dimensions and the different elements of trading systems.

Research addressing these two points should be an interesting avenue to explore in the future.

References

Admati, A.R. and P. Pfleiderer, 'A Theory of Intraday Patterns: Volume and Price Variability,' *Review of Financial Studies*, 1988, 1: 3-40.

Affleck-Graves, J., S.P. Hegde and R.E. Miller, 'Trading Mechanisms and the Components of the Bid-Ask Spread,' *Journal of Finance*, 1994, 49: 1471-1488.

Berkman, H., 'The Market Spread, Limit Orders, and Options,' *Journal of Financial Services Research*, 1993, 5: 399-415.

Bessembinder, H. and P.J. Seguin, 'Price Volatility, Trading Volume, and Market Depth: Evidence From Futures Markets,' *Journal of Financial and Quantitative Analyses*, 1993, 28: 21-39.

Black, G.D., 1986, Success and Failure of Futures Contracts Theory and Empirical Evidence. Monograph 1986-1, Salomon Brothers Center for the Study of Financial Institutions, New York.

Brorsen, B., 'Liquidity Costs and Scalping Returns in the Corn Futures Market,' *Journal of Futures Markets*, 1989, 9: 225-236.

Chan, L.K.C and J. Lakonishok, 'Institutional Trades and Intraday Stock Price Behavior,' *Journal of Financial Economics*, 1993, 33: 173-199.

Chan, L.K.C and J. Lakonishok, 'The Behavior of Stock Prices Around Institutional Trades,' *Journal of Finance*, 1995, 50: 1147-1174.

Chordia, T. and A. Subrahmanyam, 'Market Making, the Tick Size, and Payment for Order Flow: Theory and Evidence,' *Journal of Business*, 1995, 68: 543-575.

Chow, G.C., 'Technological Change and the Demand for Computers,' *American Economic Review*, 1967, LVII: 1117-1130.

Christie, W. and P. Schultz, 'Market Structure and Liquidity: a Transaction Data Study of Exchange Listing,' *Journal of Financial Intermediation*, 1994, 3: 300-326.

Christie, W. and P. Schultz, 'Market Structure and the Intraday Pattern of Bid-Ask Spreads for NASDAQ Securities,' *Journal of Business*, 1995, 69: 35-60.

Cuny, C.J., 'The Role of Liquidity in Futures Market Innovations,' *Review of Financial Studies*, 1993, 6: 57-78.

Domowitz, I., 'A Taxonomy of Automated Trade Execution Systems,' *Journal of International Money and Finance*, 1993, 12: 607-631.

Domowitz, I.,'Equally Open and Competitive: Regulatory Approval of Automated Trade Execution in the Futures Markets,' *Journal of Futures Markets*, 1993, 13: 93-113.

Fama, E.F., 'Efficient Capital Markets II,' *Journal of Finance*, 1991, 46: 1575-1617.

Foster, F.D. and S. Viswanathan, 'The Effect of Public Information and Competition on Trading Volume and Price Volatility,' *Review of Financial Studies*, 1993, 6: 23-56.

Franses, P.H.,'Fitting a Gompertz Curve,' *Journal of Operational Research Society*,' 1994a, 45: 109-113.

Franses, P.H., 'Modelling New Product Sales; an Application of Cointegration Analysis,' *International Journal of Research in Marketing*, 1994b, 11: 491-502.

French, K.R. and R. Roll, 'Stock Returns Variances: the Arrival of Information and the Reaction of Traders,' *Journal of Financial Economics*, 1986, 17: 5-26.

Fuller, W.A., *Introduction to Statistical Time Series*, Wiley, New York, 1976.

Gemmill, G., 'Margins and the Safety of Clearing Houses,' *Journal of Banking and Finance*, 1994, 18: 979-996.

Oliver, K. and R.E. Verrecchia, 'Market Liquidity and Volume Around Earnings Announcement,' *Journal of Accounting and Economics*, 1994, 17: 41-67.

Powers, Mark J., 'Thin Markets a Regulatory Perspective, in Pricing Problems in the Food Industry,' Madison, WS:N.C. Project 117, Monograph 7, February 1979.

Roll, R., 'A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market,' *Journal of Finance*, 1984, 39: 1127-1139.

Smith, T. and R.E. Whaley, 'Estimating the Effective Bid-Ask Spread From Time and Sales Data,' *Journal of Futures Markets*, 1994, 14: 37-455.

Stein, J.J., *International Financial Markets: Integration, Efficiency, and Expectations*, Blackwell, Oxford and Cambridge, 1991.

Stewart, J., Econometrics, New York: Philip Allan, 1991.

Stoll, H.R., 'Inferring the Components of the Bid-Ask Spread: Theory and Empirical Tests,' *Journal of Finance*, 1989, 44: 115-134.

Thompson, S.R. and M.L. Waller, 'The Execution Cost of Trading in Commodity Futures Markets,' *Food Research Institute Studies*, 1987, 20: 141-163.

Thompson, S.R. and M.L. Waller, 'Determinants of Liquidity Costs in Commodity Futures Markets,' *Review of Futures Markets*, 1988, 7: 110-26.

Thompson, S.R., M.L. Waller and D. Seibold, 'Comparison of Liquidity Costs Between the Kansas City and Chicago wheat futures contracts,' *Journal of Agricultural and Resource Economics*, 1993, 18: 185-197.

Wagner, W.H. and M. Edwards, 'Best Execution,' *Financial Analysts Journal*, 1993, January-February, 65-71.

Ward, R.W and R.M. Behr, 'Market Liquidity in the FCOJ Futures Markets,' *American Journal of Agricultural Economics*, 1974, 56: 150-154.

Ward, R.W, and R.M. Behr, 'Futures Trading Liquidity: an Application of a Futures Trading Model,' *Journal of Futures Markets*, 1983, 3: 207-724.

Ward, R.W. and F.A. Dasse, 'Empirical Contributions to Basis Theory: the Case of Citrus Futures,' *American Journal of Agricultural Economics*, 1977, 59: 71-80.

Working, H., 'Speculation on Hedging Markets,' *Food Research Institute Studies*, 1960, 1: 185-270.

Working, H..'Price Effects of Scalping and Day Trading,' Selected writings of Holbrook Working, Ann Peck, Ed., 1977, Chicago: Chicago Board of Trade:181-193.

Notes

1. In the literature trading activity is often used as an indicator for market liquidity. However, Park and Sarkar (1994) showed that, in the case of the S&P 500 index futures contract, changes in trading activity levels may be a poor indicator of changes in market liquidity.

2. This list does not pretend to be exhaustive.

3. The resistance price level marks the upper and lower-bound between which the price fluctuates according to the participants if the equilibrium price is constant. The equilibrium price is determined by fundamental economic factors.

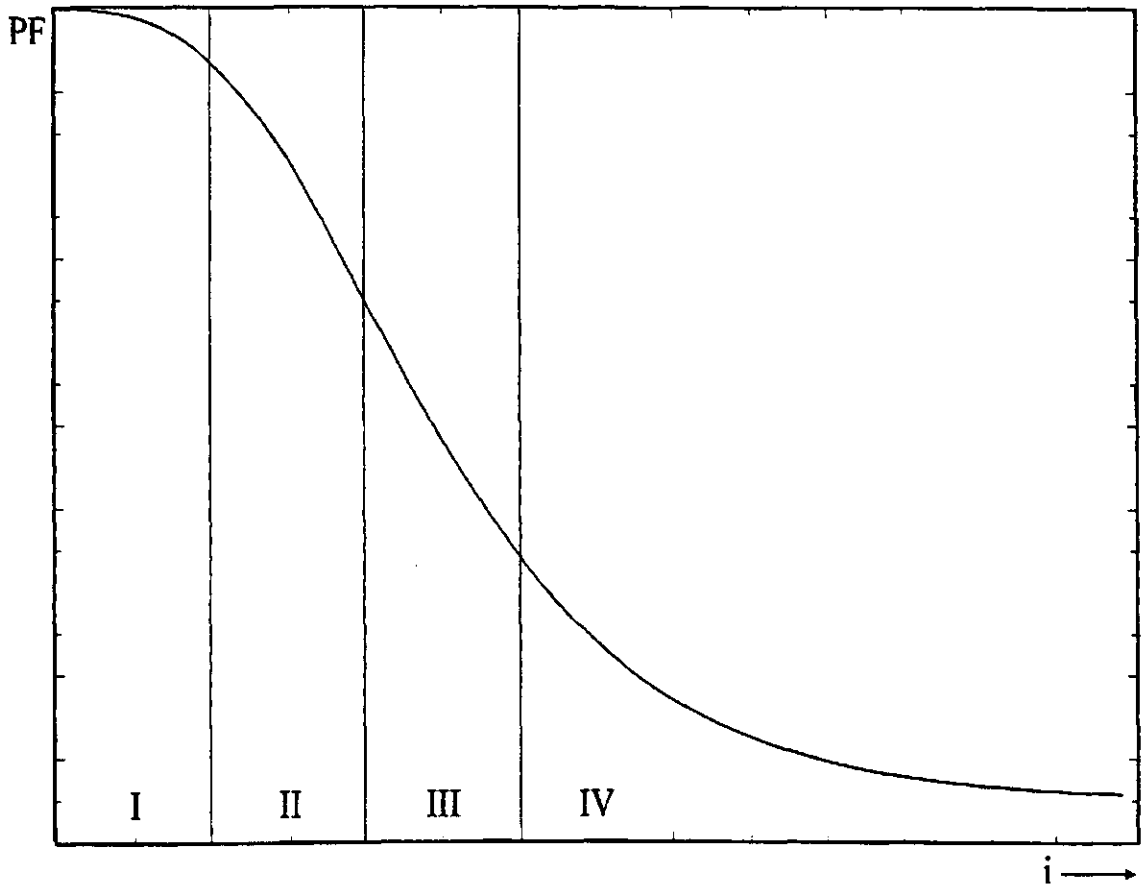

Figure 1. Price pattern of a sell order in a thin market.

Figure 1 depicts the price path of a sell order. On the vertical axis the futures price per contract traded is given where PF is the price realized when entering the futures market. On the horizontal axis the successive contracts traded are given, where the serial number of the futures contract is denoted by i. i=1 is the first contract traded, i=2 is the second contract traded and so on.

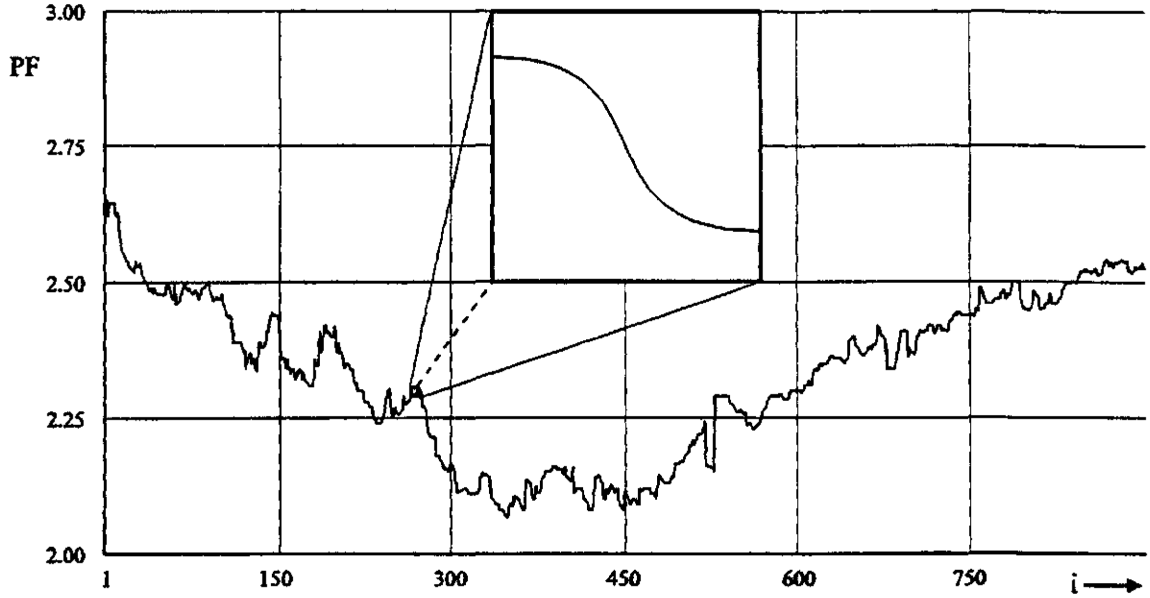

Figure 2. Futures price path.

Figure 2 depicts a graph of the futures prices per contract in chronological order. On the vertical axis the futures price per contract traded is given, where PF is the price realized when entering the futures market. On the horizontal axis the successive contracts traded are given, where the serial number of the futures contract is denoted by i . i=1 is the first contract traded, i=2 is the second contract traded and so on.

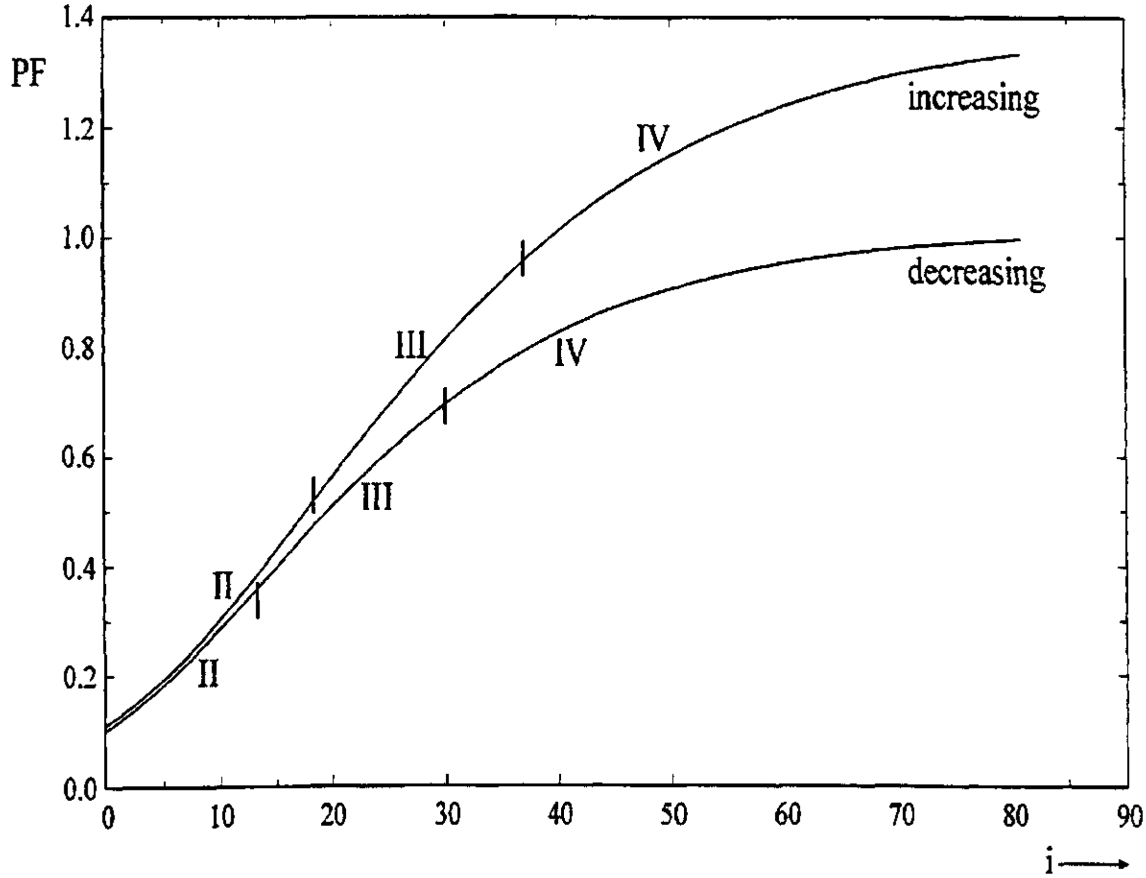

Figure 3. The Gompertz curve for the potato futures contract delivery April.

The figure depicts the Gompertz curve for increasing and decreasing price paths. On the vertical axis the futures price per contract traded is given, where PF is the price realized when entering the futures market. On the horizontal axis the prices of successive contracts traded are given, where the serial number of the futures contract is denoted by i. i=1 is the first contract traded, i=2 is the second contract traded and so on.

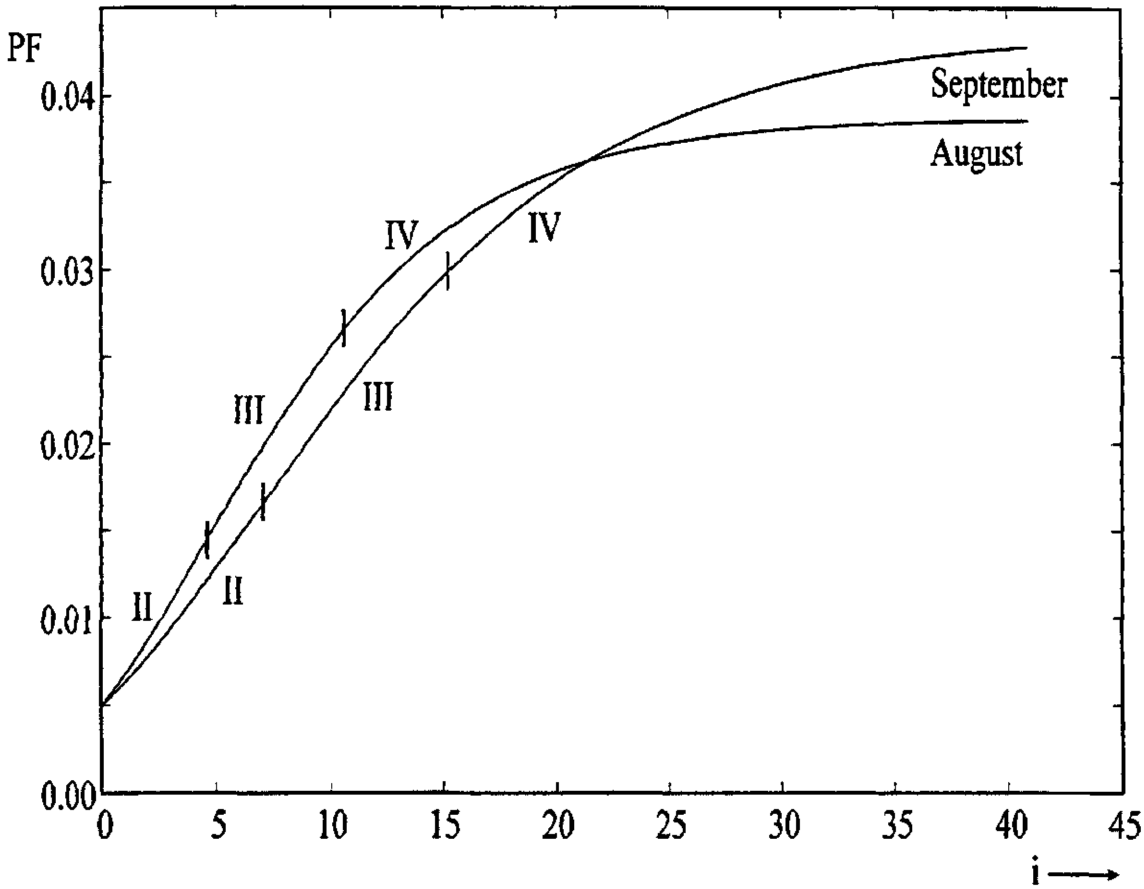

Figure 4. The Gompertz curve for hogs futures contracts deliveries August and September.

The figure depicts the Gompertz curves for hogs delivery August and hogs delivery September. No distinction is made between upward- and downward-sloping price paths, because they can be described by the same Gompertz curve. On the vertical axis the futures price per contract traded is given, where PF is the price realized when entering the futures market. On the horizontal axis the successive contracts traded are given, where the serial number of the futures contract is denoted by i. i=1 is the first contract traded, i=2 is the second contract traded and so on.