Nonlinear Transaction Pricing in the Securities Trading Value Chain

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Abstract

Most of the research on transaction costs in the market microstructure literature focuses on implicit transaction costs. Research on the design of price schedules for explicit transaction fees is rare. This paper analyzes and classifies different price schedules and discusses their application to the market transaction business. The discussion highlights design issues and the need for a structured approach for price schedule design in the context of market engineering.
In order to get some insights into customer order behavior, we conduct a trading experiment where participants trade virtual stocks on an electronic platform within a time period of three weeks. During three weeks, participants face transaction fees of different types. Order frequency and volume is measured and related to the price schedule in place. We find that both variables are influenced by transaction fees. We also try to identify price elasticities for groups with different income and use this information for a structured approach towards a nonlinear price schedule design.

1 Introduction

1.1 Motivation

In recent years, the global exchange landscape has been undergoing a constant change: Trading venues where trades have taken place in open outcry auctions are replaced by electronic trading systems. Continuous trading usually replaces trading via intermediaries like specialists who

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determine prices and supply liquidity in single securities. Some traders fear that market quality could decrease if human judgment by intermediaries in the securities trading value chain is replaced by automatic matching algorithms. In some markets, e.g. the New York Stock Exchange (NYSE), or in some types of securities, e.g. covered warrants, stock exchanges still use some kind of specialist system in order to guarantee a certain order execution quality. In coming years, market operators will have to decide whether there is still need for human intermediaries.

Another development which has influenced the electronic value chain in securities trading in recent years is the use of order routing systems and market access infrastructure which is provided to retail customers by online brokers. For the first time, retail investors get direct electronic access to trading venues world wide. The increasing trading volume and the decreasing costs for transaction services at the same time require ongoing disintermediation of processes. Brokerages and market operators must develop innovative business and pricing models to stay competitive in the long run.

1.2 Objective and Outline

This paper is organized as follows: In section 2, an introduction to transaction fee models is presented. A motivation, related research and a formal representation of transaction fees are discussed. Furthermore, some real-life examples from stock exchanges are given. In section 3, an experiment on transaction fees is introduced and some first results are outlined. Section 4 concludes with an outlook on further research questions.

2 Transaction Fee Models

2.1 Motivation

Pricing of transaction services in electronic financial markets has been undergoing a continuous change. Recently, the New York Stock Exchange announced a major change in their transaction fee schedule which took effect on August 1, 2006. This initiative represented the first significant price change in many years, most probably driven by the acquisition of Archipelago, the development of the NYSE Hybrid market, and NYSE’s attempts to foster electronic trading.

When the traditional New York Stock Exchange announced its new price schedule, so too did the fully-electronic NASDAQ Stock Market and changed the pricing scheme for NYSE-listed securities. Transaction fees seem to play an important strategic role for exchanges and marketplaces.

Recent developments in the design of price schedules such as “free trade” and “no fee” offers by banks and brokerages emphasize the relevance of research on the structured engineering of price schedules and customer price sensitivity regarding transaction services. Obviously, customers are aware of different price schedules and take them into consideration when they decide about placing their order.

In general, price schedules of transaction services may depend on several variables, including the value and the volume of the order, both on a per-trade and a per-period basis. Another variable that may be employed is the sum of transaction fees already paid in a specific period of time. Depending on these variables, price schedules can be classified into different classes of schedules, differing in complexity, depth, and therefore ability for price discrimination. The classification and discussion of price schedules and is regarded as a contribution towards the structured approach of price schedule design in the context of market engineering [WeHN03].

2.2 Related Research

Much work has been done around transaction costs in financial markets but most of the literature focuses on implicit transaction costs like the spread or the market impact. Commissions and fees are usually neglected.

Wilson [Wils93] published a monograph about nonlinear pricing and tariff design in the context of electricity and telephone markets which has become a standard reference in the economic pricing literature. Mathematically founded, he showed how tariffs should be designed and based his research on economic theory. For practitioners, this approach does not seem to be easily applicable since the results are based on a set of assumptions which have to be estimated in order to find the optimal solution. Furthermore, Wilson does not take marketing and communication aspects into account.

Dolan [Dola87] integrates the economics and marketing literature and presents an overview of possible motivations for quantity discounts. He narrows his tariff design to three basic types which he compares with each other. The same has been done by Leland and Meyer [LeMe76] who compare two-part pricing and block pricing. Although Dolan presents some price schedule design issues for pricing managers, these could be further expanded and detailed to be an integral part of the market engineering approach.

In the German pricing literature, Hermann Simon [Simo82] presents the basic principles of price management in a broader marketing context. Tacke [Tack89] focuses on non-linear pricing especially with two-part and two-block schedules described in [Dola87]. He presents some good examples for the application of price discrimination and shows when to use which kind of price schedules. Skiera [Skie99] finally narrows the application domain to services and discusses price discrimination in that context.

2.3 Nonlinear Transaction Fee Schedules and Design Parameters

Suppliers of transaction services have several possibilities to charge for their services. The types of price schedules that are most commonly used are uniform schedules where the price is proportional to the quantity purchased, and nonuniform schedules where there are price breaks depending on the volume.

2.3.1 Types of Nonlinear Price Schedules

A price schedule specifies the relation between the marginal price per unit and the number of units per transaction. Most generally, a price schedule can be represented by a function R(q) where R(q) is the transaction fee for the order size q.

Nonlinear price schedules can be classified into two-part schedules, two-block schedules (which can be easily extended to n-block schedules), and all-units quantity discount schedules.

(i) Two-part price schedules consist of a fixed fee F and a constant marginal price p. Essentially, the customer pays the fixed fee F for the right to place an order at all, and a variable fee pq depending on the size q of the order. The two-part schedule can be written as:

$$R(q) = \begin{cases} F + pq, & q > 0 \\ 0, & q = 0 \end{cases}$$

(ii) Two-block price schedules consist of two different marginal prices p_1 and p_2 where p_1q is charged for an order size of up to x units. If the order is greater than x, the first x units are priced at p_1x, and all subsequent units are priced at p_2 per unit. This can be written as:

$$R(q) = \begin{cases} p_1 q, & 0 \le q \le x \\ p_1 x + p_2 (q - x), & q > x \end{cases}$$

(iii) All-units quantity discount schedules consist of several different marginal prices which are applied for each unit depending on the total size of the order. That means if a certain quantity level is exceeded, the corresponding marginal price applies to all units. The mathematical formula for the all-units quantity discount schedule is as follows:

$$R(q) = \begin{cases} p_1 q, & 0 \le q < x \\ p_2 q, & q \ge x \end{cases}$$

As a result of the different marginal prices associated with different quantities, all-units quantity discount schedules require that there are discontinuities in the R(q) function. In reality, if a customer places an order of a size that is slightly less than a breakpoint, a fee associated with the corresponding breakpoint size will typically be charged. This results in the effective all-units quantity discount schedule which therefore must have flat portions at the breakpoint sizes. Figure 1 summarizes all types of price schedules discussed above.

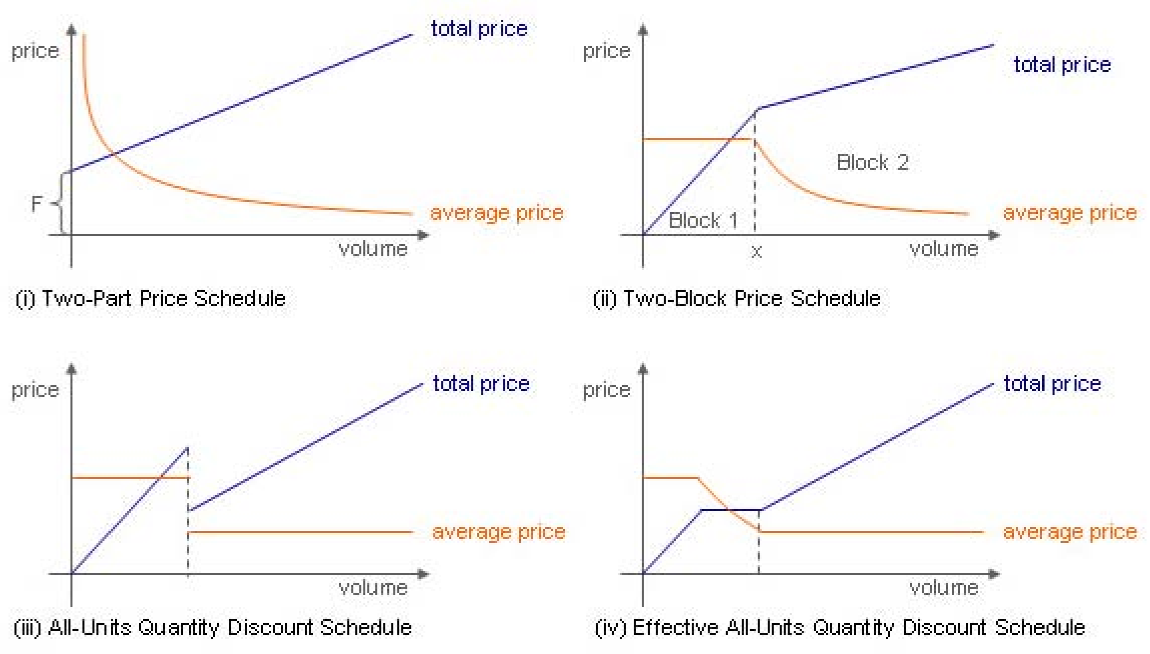

Figure 1: Price Schedule Types

2.3.2 *Design Parameters*

Several design issues are discussed in [Dola87], especially price schedule type, price schedule complexity, price schedule depth, and the qualifying unit base. Type refers to the question whether to use incremental or all units quantity discounts, complexity addresses the number of price breaks, depth the magnitude of the discounts, and qualifying unit base is the dependent variable which is used to determine whether a customer qualifies for a discount.

Concerning the price schedule type parameter, we can constrain design efforts to support n-block price schedules since a two-part schedule can easily be written as an equivalent two-block schedule with a prohibitively high marginal price in the first block effectively representing a fixed fee for the customers.

The price schedule complexity parameter has to be considered in a marketing context. Although it can be shown that n+1 breaks are strictly better than just n breaks [Moor84], it seems to be fair to assume that customers prefer a simpler schedule over a more complex one with a higher number of price breaks. Moreover, less complicated price schedules are cheaper to communicate and calculate.

Price schedule depth is an important economic design parameter because it has to be considered in the context of customer price elasticity of demand and willingness to pay expressed through the demand profile.

The qualifying unit base is a key parameter for the development of a price schedule framework including price schedules, rebates, caps, and floors. For example, the unit base could either be quantity, volume (in terms of monetary units), or average transaction fees paid. Which one of these variables are employed in the price or rebate schedule is a question whether it is needed to encourage high value transactions or influence the size of the aggregated transaction volume over a specified period of time.

2.4 Applications

2.4.1 New York Stock Exchange

Before the New York Stock Exchange introduced its new price schedule this summer, a multi-block schedule was in place that differentiated the transactions according to the number of shares. No charge was levied for system orders under 2,100 shares. For orders with a size between 2,100 and 5,000 shares, a transaction fee of $0.0023 per share was charged. For order sizes above 5,000 shares, there was a charge of $0.0001 for each additional share. In effect, customers paid $11.50 for the first 5,000 shares and $0.0001 for every share which was above the breakpoint of 5,000. The total transaction fee was capped at $80.00.

The NYSE then eliminated the free orders and employed a uniform marginal price of $0.00025 per share capped at $80.00 per transaction. Figure 2 illustrates the changes in the price schedule.

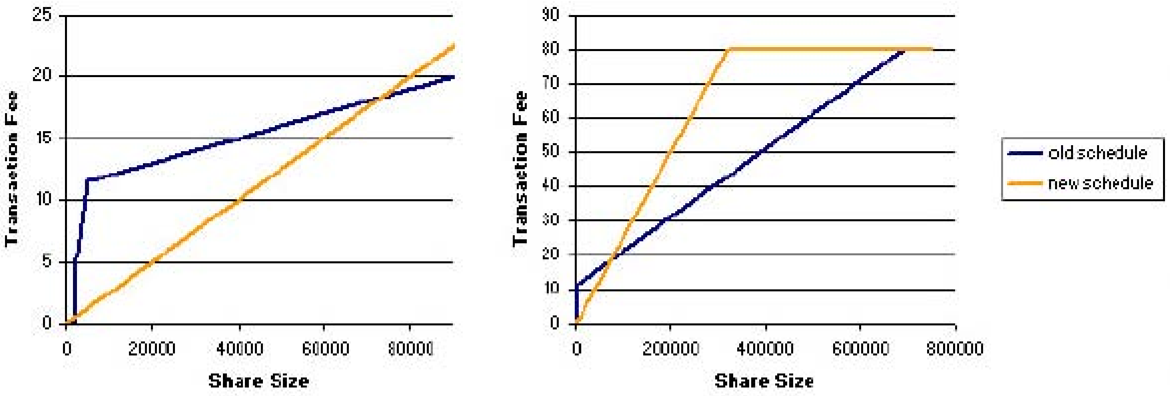

Figure 2: Comparison of the NYSE price schedule before and after the change. The graph on the left side is a magnification of the graph on the right side.

In addition to the $80 cap per transaction, the NYSE has established a monthly cap of $750,000 which means that companies do not pay more than $750,000 per month. In effect, this constitutes an incremental rebate of 100% of the transaction fee since it applies to all future transactions after the qualifying amount has been reached.

2.4.2 NASDAQ Stock Market

The price schedule of the NASDAQ differs from that of the NYSE in a couple of points. Most importantly, the fully-electronic NASDAQ differentiates between removing and adding liquidity. Removing liquidity (i.e. placing a marketable order) for NYSE-listed securities is charged with a uniform price of $0.0007 per share whereas adding liquidity (i.e. placing a non-marketable limit order) qualifies for a rebate of $0.0005 per share executed. In addition, customers have to qualify for the rebate by reaching an average daily share volume of 5 million shares. If customers add more than 10 million shares in daily average, a rebate of $0.0006 is given.

2.4.3 ebay

As another example of an electronic marketplace, the internet auction site ebay.com uses an incremental three-block price schedule for its execution fees which are based on the final closing price (which represents the quantity dimension in our formulation above). Price breaks are at the $25 and the $1,000 level. The marginal prices in each block are decreasing and set at 5.25% in the range from $0.01 to $25.00, 3% in the range of $25.01 to $1,000.00, and 1.5% for the trailing block with final closing prices greater than $1,000.00. Figure 3 illustrates the price schedule.

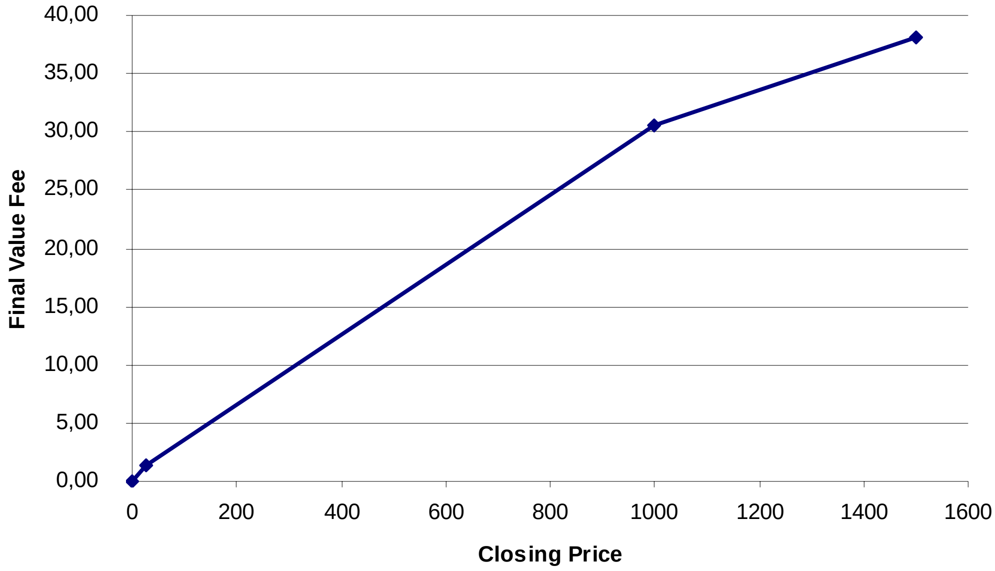

Figure 3: Ebay's Block Pricing Schedule

2.5 Section Summary

For the examples discussed in the previous section, the main motivation for nonlinear pricing is partial price discrimination. Due to the quantity discounts, the average price of small orders is higher than the average price of large orders. According to [Buch53], the underlying criterion for this motivation must be that the demand schedule of customers who place smaller orders is more inelastic over the relevant price range than that of customers who place large orders.

Why did the NYSE eliminate the price breaks at 2,100 and 5,000 shares and introduced a uniform price for the sizes of up to 320,000 shares instead? One explanation is that the NYSE wanted to simplify its price schedule for marketing purposes. Another explanation is that the NYSE took the chance to increase revenues when they had the opportunity. The price change allowed them to participate in the volume growth at the NYSE on the listed side of trading.

Such an effect on revenues must be considered in the light of customers' willingness to pay and customers' price elasticity of demand. Thinking in terms of price discrimination, altering the price schedule in such a way presumes that (i) customers with small orders up to 2,100 shares are price insensitive, (ii) the 5,000 shares price break has not proven to be useful for customer segmentation, and (iii) customers with an order size of 73,000 to 690,000 shares are either price insensitive or they are expected to change their order behavior since they have to pay more with the new price schedule than with the old one.

The NASDAQ example illustrates how important it is for electronic exchanges to attract liquidity with an innovative price schedule. This price schedule relies on the fact that customers with urgent trading needs are less price sensitive than customers who do not need to trade immediately and thus place non-marketable orders.

The ebay.com price schedule illustrates the need for companies to employ price discrimination for profit maximization. It seems fair to assume that the majority of products offered on ebay is priced below the $25 breakpoint, therefore average transaction fees are highest in this range in order to increase profits. Additionally, customers are assumed to be less price sensitive in this range than in ranges of higher closing price values.

To conclude, a structured approach for the design of price schedules is necessary in order to accomplish the different goals of companies in the execution business. Future work needs to be done on integrating price schedule design into the holistic market engineering process. Computer Aided Market Engineering [WeNH06] should be extended to include tools to analyze customer preferences and suggest optimal design parameters for price schedules based on economic as well as marketing principles.

3 Transaction Fee Experiment

3.1 Motivation

The previous sections have shown that information and knowledge about different customer types is necessary to design an optimal profit-maximizing price schedule. While empirical research on the distribution of transaction volume and frequency is needed to identify different customer segments, further research has to focus on the order behavior of customers when being confronted with changing price schedules.

In order to get an understanding about customer behavior following a change of the transaction fee schedule, a field experiment is conducted in which there are (a) different customer segments according to their initial endowment and (b) different transaction fees over the total trading period of three weeks. The control over the design of the transaction fee schedules makes it possible to draw conclusions about the influence of transaction fees on the order behavior of investors.

3.2 Research Questions

There are several research questions that arise in the context of nonlinear transaction fee pricing.

- What is the price elasticity of demand in the context of transaction services? Are customers sensitive to price changes at all? Are there other – more important – determinants of their trading decision?
- Can investors be segmented into different groups that differ in their (a) price elasticity and (b) willingness-to-pay?
- How do investors react to changing price schedule types, i.e. do they take their distinctive features (e.g. price breaks in the stepwise price schedule) into account when placing their orders?
- How does trading volume and the number of transactions change when the transaction fee schedule changes?

Some of the questions above have been partly answered in related literature. [Epps76] develops a probability model which implies that the expected number of transactions per unit time is a decreasing linear function of the ratio of transaction cost to the security's price per share. Furthermore, the expected number of shares exchanged and the expected trading volume are decreasing functions of this ratio. He estimates these function for 20 stocks and finds that volume is indeed measurably responsive to changes in transaction costs. Furthermore, Epps estimates the demand for brokers' service to be -0.25. This estimation, however, is based on transaction records of the 1970s – today, people are likely to react very differently.

3.3 Experimental Design

We have conducted a trading experiment where participants could trade virtual stocks on an electronic platform within a time period of three weeks. During three weeks, participants faced transaction fees of different types. Order frequency and volume were measured and related to the price schedule in place.

3.3.1 Subjects and Groups

60 mostly undergraduate students in information engineering and management served as subjects for the experiment. They were grouped into 3 groups of traders: A, B, and C.

Group A was used as a benchmark group with a high initial endowment of shares and money and no transaction fees. Group B also had the high endowment but faced transaction fees during the experiment. Group C also faced transaction fees – the same as group B – but started with a much lower endowment, i.e. low income.

All groups were paid according to their trading performance. In order to encourage them to trade a certain amount of stocks, a weekly minimum trading volume requirement was in place which accounted for 10% of the overall income. If this requirement wasn't met in all three weeks, the payment was decreased to zero.

3.3.2 Transaction Fee Schedules

For groups B and C, a transaction fee schedule was in place that changed at the beginning of week two and three. Subjects were not told that (a) there was going to be a change of transaction fees, and (b) how that change would look like.

In the first week, the announcement of the transaction fee was:

- You are charged a fixed fee of 30 monetary units per executed order and a variable commission of 5% of the transaction volume. The minimum transaction fee, however, is 50 monetary units, the maximum fee 250 monetary units.

At the beginning of the second week, the following transaction fee schedule was announced:

up to a transaction volume of	monetary units	you are charged	monetary units
	500		50
	1500		100
	3000		150
	6000		200
from	6000	you are charged	250

The third week started with an announcement as follows:

- For each transaction, independent of the transaction volume, you are charged a fixed amount of 150 monetary units.

The different transaction fee schedules are summarized in the following figure:

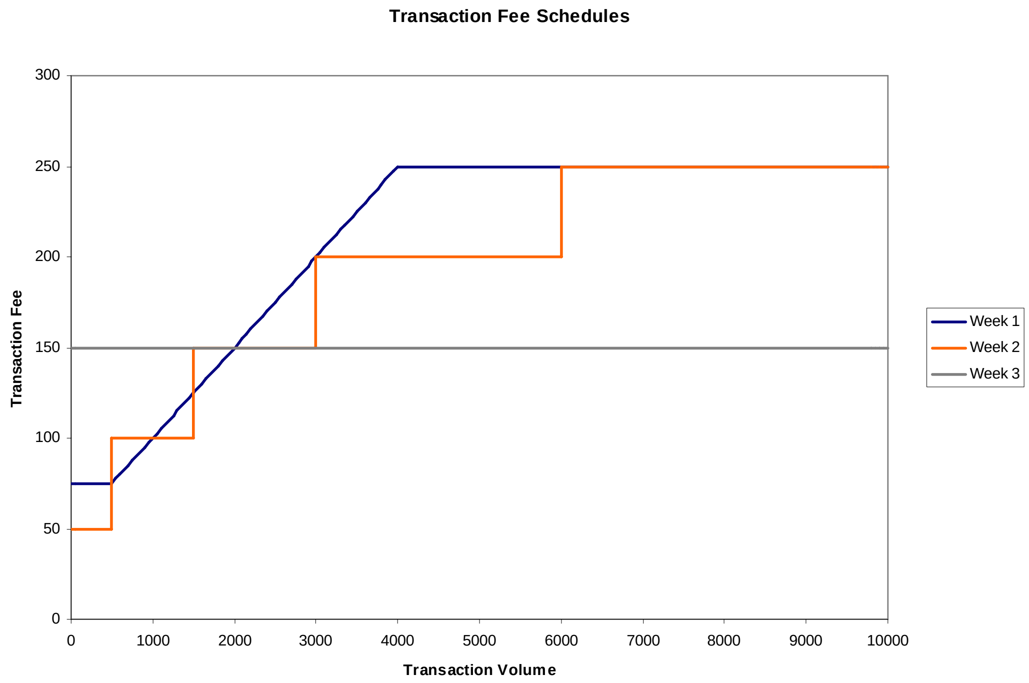

Figure 4: Transaction Fee Schedules for Weeks 1 to 3

3.3.3 Incentive Schemes

As mentioned above, subjects were all paid according to their performance. Since all participants of one group traded in the same continuous double auction, the game was a zero sum game where the amount gained by one part of the group has been lost by the other. Therefore, cheating wasn't attractive for the subjects. Since the transaction fees were subtracted from the payment, subjects had an incentive to minimize transaction fees in order to get a higher payment.

3.4 First results

We have focused on the average number of orders in each group. According to the changing fee schedules, the number of orders should have been decreasing, and the average transaction volume should have increased.

In the following graphs we have depicted box plots of the average number of orders in each group. We can see the order frequency (i.e. the actual number of orders per week) has decreased in groups B and C (where there were transaction fee schedules in place) whereas in group A, the average number of shares has remained constant (even with an increase from week 1 to week 2).

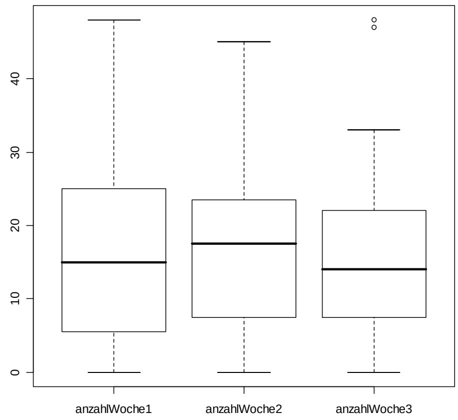

Figure 5: Average Number of Orders (Group A)

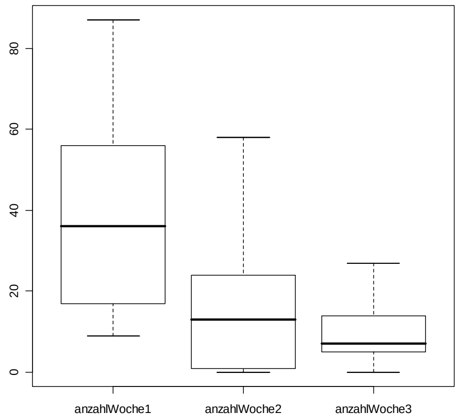

Figure 6: Average Number of Orders (Group B)

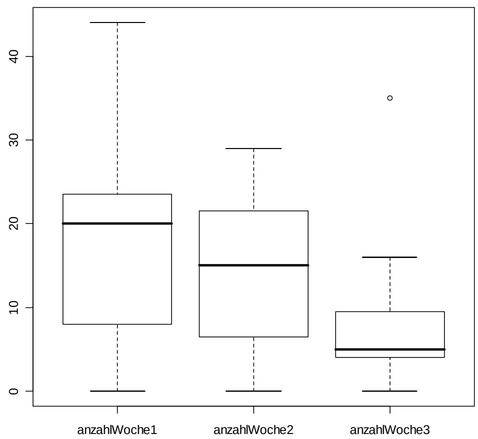

Figure 7: Average Number of Orders (Group C)

First results indicate that there is a significant increase in the average number of orders per period in the groups facing transaction fees whereas we do not find an increase in the number of orders in the test group without transaction fees.

4 Conclusion and Outlook

This paper has presented a classification of transaction fee schedules, a formal representation, and some real-world examples of nonlinear transaction fee schedules. In the second part of the paper we have outlined a field experiment where we investigated the effect of changing transaction fees on the order behavior of subjects. While there are first promising results, there are a couple of points which still have to be addressed:

- Analytical solution: Based on the segmentation of customers, an analytical solution should be derived to determine the profit-maximizing price schedules. In particular, how many price breaks are possible, where are the price breaks depending on the segmentation, and what kind of price schedules are optimal.
- The objective of the stock exchange is not always profit-maximization. Some stock exchanges prefer to maximize customer welfare and act as not-for-profit organizations. In designing the optimal price schedule, this also has to be taken into account.
- Follow-up experiments should be designed to address questions which have not been known before. Based on the results of the experiment described, laboratory experiments should provide more insights into specific behaviour of the subjects.
- Real-world data from stock exchanges should be analyzed to verify the effect that changing transaction fees have on order behavior.

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