Czech Experience with Market-Maker Trading System

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Abstract: We study the evolution of trading in a market-maker trading system (SPAD) introduced to the Prague Stock Exchange in 1998. We find that the new system succeeded in increasing the transparency of the market, improved the price discovery function of the exchange, and that investors have benefited from lowered spreads. From this viewpoint, it may be an example for other markets where lack of transparency negatively affects the price discovery function and trading costs. However, we find no evidence that the extent of informed trading decreased over time.

Keywords: trading systems, informed trading, emerging markets

JEL Classification: G14, G15, P34, P59

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I. INTRODUCTION

Czech equity market developed very rapidly after its market capitalization; both trading volume and the number of listed companies soared in the first half of the 1990s. However, this was due solely to the listing of shares distributed in coupon privatization, as virtually no new capital was raised on the market.[1] As opposed to the classic gradual way of market development, more than seventeen hundred shares were simply transferred to the Prague Stock Exchange (PSE) without any listing requirements, creating a complicated and non-transparent market environment. Market regulation lagged significantly. Insider trading, price manipulation, fraud in the investment funds industry, and abuses of minority shareholder rights eroded much investor confidence.[2]

The government and the PSE have introduced a number of reforms over the years in an attempt to improve the functioning of the equity market. The legal framework has been strengthened, primarily to provide more protection to minority shareholders, and a Securities Commission has been created. At the PSE, reforms included the introduction of different market tiers (with different qualifications and information-disclosure requirements), the delisting of a large number of shares, changing the secondary market organization from a single price auction market to a continuous price auction market, and, most recently, the

[1] With the exception of a single case, there have been no initial public offerings on the PSE since its creation.

[2] Besides abundant anecdotal evidence, Hanousek and Podpiera (2002) estimated the extent of informed trading and their results suggest that informed trading is indeed considerably higher than in developed markets.

introduction of a market-maker system. Although these reforms have not been completely successful as is evident from the fact that the PSE has not become a place where Czech (or any other) companies raise new capital, some of the technical reforms have been helpful in increasing the transparency of the Czech equity market and in decreasing trading costs. [3]

This paper analyzes one of these technical reforms, the introduction of a market-maker trading system at the PSE. This trading system (SPAD) was introduced in 1998 for the most liquid Czech stocks with the aim to increase the transparency of the market and lower transaction costs for investors. The goal of the paper is to examine whether this aim was accomplished and what role this system has been playing in the Czech equity market. Many equity markets in emerging and developing countries suffer from problems of limited liquidity, inadequate transparency, and high trading costs. The introduction of SPAD—if successful—could serve as an example of the benefits this type of trading system can bring for other countries. To assess whether SPAD indeed increased transparency and lowered trading costs, we examine the distribution of order flow among different market segments, the development of trading spreads, and the extent of informed trading.

[3] Paradoxically, several studies mention stronger links between economic factors and the stock market in the early years compared to later development (Hanousek and Filer, 2000), or lower predictability of returns in the early years (Rockinger and Urga, 2000).

II. THE SPAD SYSTEM

A. Launch of the SPAD system

Before 1998, the price-setting central market at the Prague Stock Exchange (PSE) was formed by an auction system, with a continuous auction for the most liquid equities and a fixed auction system for other shares. These auctions, however, were rather illiquid and the vast majority of trades were executed off-market and settled as direct and block trades on the PSE.[4]

Even within the PSE, trades between its members were conducted either through a so-called central market which had a price discovery function or via the so-called direct and block trades. The pattern of trading volumes as indicated in Table 1 is rather striking. While shortly after launching the PSE in 1994 direct and block trades formed less than 75 percent of the overall volume, in 1996 and 1997, the price-setting central market only accounted for approximately 10 percent of total trading volume. The price discovery function of the market, as well as its transparency, was compromised. Only a fraction of the trading volume determined reported prices, which at that time were not representative of the true valuation of shares.

<INSERT TABLE 1>

[4] Since the very beginning, investors have had three options for processing orders: 1) via a PSE broker; 2) dealing on the RM-System (an over-the-counter-system); and 3) dealing off-market, settling trades directly at the national securities registry, called the Securities Center (SCP).

Direct and block trades were concluded over the counter and the lack of transparency increased the trading costs of investors and decreased the attractiveness of the Czech equity market. The Stock Exchange gradually developed a system for reporting and publishing direct and block trades, but it was neither reliable nor efficient since its enforcement was weak and there was a significant lag between the time trades were reported and published.

Let us note that until mid-1997 PSE members were allowed to deal privately and settle trades even outside of the PSE at the national securities registry, called the Securities Center (SCP), but this is no longer the case. Nevertheless, they still have been able to go off-market and settle trades with other PSE members through the Univyc (a subsidiary of the PSE). This situation forced the Prague Stock Exchange to introduce a major reform of the trading system. In May 1998, a new market-maker system for the most liquid shares was launched.

B. Design of the System

The SPAD system is formed by market makers who are obliged to quote prices for sale and purchase. The whole system is computer-based, and all the market makers and members of the PSE are able to see all quotes and trades. Members of the PSE who apply and are approved serve as market makers in the SPAD system.

Individual market makers are allowed to quote different ask and bid prices, but the maximum spread for each of them is limited. A committee of the PSE sets the exact limits depending on a number of factors and, based on the development of the stock’s price, the

maximum spread is irregularly changed. Overall, the spread has amounted to approximately 2.5 percent of the stock's price.

The system operates in two phases, closed and open. The closed phase can be viewed as a technical device that allows market makers to clear the trades that they did not manage to conduct during the open phase. The actual trading occurs during the open phase of the system, which lasts from 9.30 a.m. to 4.00 p.m. each trading day and during which the market makers quote firm prices for a fixed number of shares of each stock.

The size of trading lots varied from 200 shares for Tabák (Philip Morris ČR) to 20,000 shares for Unipetrol or ČEZ during our sample period.[5] The size of the lots was occasionally changed depending on price development of the stock, but generally speaking the trading lots were rather large compared to both the overall trading volume and the capital base of some of the market makers.[6]

The quotes in the system are firm in the sense that if the quote is the best available on the market and if another party reacts to it by entering an instruction for a trade, the market maker is obliged to enter his instruction so that the trade can be executed. Blocks of shares that differ in size from the trading lot can be settled through the system as well, but these trades are negotiated in advance over the phone and, in fact, are not very frequent.

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[5] The first sample period starts in March 1999 and ends in December 2001. The second sample covers the period October 1 to December 31, 2002. See below for a data description. The average exchange rate in the two sample periods is 37.4 CZK/USD and 30.9 CZK/USD, respectively.

[6] The market value of one trading lot ranged from 0.5 mn CZK to 5.3 mn CZK during the sample periods and averaged slightly below 2.0 mn CZK.

In order to limit the risk of default, there exists a standard settlement procedure and a guarantee fund into which market makers must insert a deposit, and there are procedures that come into play if one side of the trade defaults. Overall, trading in SPAD appears to be safe, since no serious problems of default have been reported since its inception.

The SPAD system was designated as the price-setting mechanism at the PSE. The average of the quotes at the end of the open phase (at 4:00 p.m.) becomes the official closing price. Shares included in the SPAD can be traded only in the system; block trades are allowed, but these must be larger than a limit set by the PSE and this limit is considerably larger than the market capitalization of the trading lots. Brokers can negotiate trades over the phone, but these trades must be inserted and executed in the SPAD system within 5 minutes.

C. Stocks Traded and Data Description

During our first sample period, which starts in March 1999 and ends in December 2001, six stocks were traded without any significant interruption. These included two telecommunication companies (SPT Telecom[7] and České radiokomunikace), two banks (Česká spořitelna and Komerční banka), a petrochemical company (Unipetrol), and an electricity generator (ČEZ). In addition, an investment fund (RIF), a construction company

[7] During the sample period, SPT Telecom was renamed to Český Telecom (Czech Telecom) and Tabák's name was changed to Philip Morris ČR.

(IPS), another bank (IPB) and a cigarette producer (Tabák) were either added to the SPAD system after our sample period started or removed before the end of 2001.[8]

The six stocks that were traded during the whole sample period are more actively traded than the others—averaging almost 40 trades a day—and have an average market capitalization of 43 bn CZK. Each of the remaining four stocks had a mere 9 trades a day and their market capitalization was considerably lower, below 10 bn CZK on average. The average daily trading volume in SPAD amounted to 700 million CZK (approximately 19 mn USD) during the sample period.[9] There is no common pattern in price development of the ten stocks during the first sample period and the profile of volumes differs substantially across the stocks. The only common feature is a significant increase of trading volume in early 2000 in the case of the six stocks that were traded during the whole sample period.[10]

The number of market makers varied during the sample period, but not dramatically. Each of the 10 stocks had, on average, approximately 9 market makers who were quoting it. The SPAD rules stipulate that there must be at least 3 market makers for each stock for it to be traded in the system. In reality, the number of market makers for each stock was considerably higher than the required minimum.

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[8] RIF was removed from the SPAD system due to its conversion to an open-ended fund, IPB shares were suspended from trading after it was put under forced administration, IPS shares were delisted after a takeover by a major foreign investor and Tabák was introduced to the SPAD system only in October 2000.

[9] At the same time, the share of the SPAD system of the whole PSE trading volume (in equities) was rather high in 1999-2001, at 96%, as it was successful in attracting order flow from the direct trades segment.

[10] Graphs depicting price and volume developments are available upon request.

Data on individual trades from SPAD have been publicly available since early 1999. The first sample covers the 34 months from March 1999 to December 2001, for which we have information about each trade conducted in the SPAD system. For each trade, our data includes a stock identification, transaction price, number of shares, time the trade was concluded, and the best bid and ask quotes at the time the transaction took place. Also, we are able to identify so-called cross trades; that is, we are able to distinguish trades that are conducted between the inventory of a market maker and the market maker's clients, since these must be reported in the system as well.

The second sample covers the period October 1 to December 31, 2002. There were some changes in the composition of shares traded within the SPAD; namely, Česká spořitelna was delisted (as a result of Erste bank controlling over 90 percent of its shares and deciding to leave the PSE) and as reciprocity, shares of Erste bank started to be traded on the PSE parallel to the Vienna Stock Exchange. There were seven shares traded on the PSE during the second sample period.

Basic characteristics of the data we used to estimate the extent of informed trading are described in Table 2.[11] Let us note that differences in trading characteristics remain very high. For instance, the most liquid Komerční banka experienced about 48 transactions per trading day which corresponds to 27 percent of all daily trades, while Unipetrol and České radiokomunikace were subject to 8-9 trades per day which represents only 5 percent of daily

[11] We use only part of the first sample period, August–November 1999 to estimate the extent of informed trading, while we use the whole first sample, March 1999–December 2001, to examine the development of operational efficiency.

trading activity. The total number of market makers per each traded stock dropped from a level above ten to a neighborhood of seven; however, *per se* this does not necessarily give any bad signal, as it is still markedly above the SPAD rules which stipulate at least 3 market makers for each stock.

III. Development of SPAD's Role and Efficiency

A. SPAD: Share of Order Flow

The most liquid stocks from the main market of the PSE were introduced to the new SPAD system in May 1998. Already in the same year, the share of trades in the price-setting central market (which included the SPAD) of the main market segment jumped to over 50 percent from just over 7 percent in the previous year (Table 1).

In the following years, the share of the price-setting central market increased further and stayed high—over 90 percent in 2000 and 2001—with a very large proportion of the volume being traded in the SPAD system. Overall, the trade volume data shows that the SPAD was successful in attracting the order away from OTC-negotiated trades that were recorded as direct and block trades at the PSE. This significantly increased the transparency of the market because information about the vast majority of trading—that is all trades in the SPAD system—became publicly available almost in real time. Also, prices quoted by the PSE (now prices from SPAD) became more reliable because they started to be based on a considerably large share of the trading volume.

It should be noted that there was a change in methodology related to the data in Table 1. The PSE started to count certain central market trades (i.e., those influencing price

formation) as direct and/or block trades[12]. Using disaggregated data from the PSE, we were able to reconstruct the trading volumes for 2002 using the same methodology. These are reported in Table 1.

B. SPAD: Operational efficiency

We attempt to measure the operational efficiency of the SPAD system by the development of the traded spread. While the posted spread is simply the difference between best ask and best bid quotes, the concept of traded spread also takes into account the fact that investors are sometimes able to obtain better prices from the market makers, and thus the effective spread paid by the investors is lower. For a detailed analysis of the traded and posted spread in the SPAD system, including intra-day developments, see Hanousek and Podpiera (2003).

Estimates of the traded spread were obtained by estimating the following equation (see Appendix II)[13]:

$$P_t - M_t = S/2*Q_t + \eta_t, \qquad (1)$$

We estimate the traded spread for 17 two-month windows in our sample period (Figure 1).

<INSERT FIGURE 1>

The average traded spread for the whole sample period varied between 0.7 percent for the most liquid SPT Telecom and 1.4 percent for the least liquid Unipetrol. The 2-month

[12] The changes refer to a category called "SPAD trades without market-maker duty". Originally all SPAD trades were treated as central market (i.e., the price discovery segment) trades, but since January 2003 SPAD trades without market-maker duty counted within the same category as block trades. More details can be found at the official PSE site www.pse.cz.

window estimates suggest that the efficiency of the SPAD system indeed increased over time. The traded spread declined during the first part of our sample period, from almost 1.5 percent to below 1.0 percent, most likely due to an increase in the efficiency of the system as market makers and, particularly, investors learned how the system worked and how they could use it to their advantage. The spread then stabilized in mid-2000 for almost all stocks. However, some stocks, including České radiokomunikace and Unipetrol saw their traded spread increase again later in the sample period, which was possibly related to increased risk connected with their announced privatization.

C. Development of the Extent of Informed Trading

We use two methods to assess the development of the importance of informed trading over time. First, we compare the estimates of the extent of informed trading for three-month periods in 1999 and 2002. Second, we examine the development of the share of the adverse selection component of the spread between March 1999 and December 2001.

We have estimated the extent of informed trading, using the same model as Hanousek and Podpiera (2002) for the last three months of 2002, i.e., we use the model developed by Easley et al. (1996). [14] The basic model is described in Appendix I and the estimation results are depicted in Table 3 below, along with the estimates reported by Hanousek and Podpiera (2002) for the time period August to November 1999.

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[13] Previously used, for instance, by Huang and Stoll (1997).

[14] Let us note that Grammig and Theissen (2003) discovered that if using the methods described in Lee and Ready (1991), all estimates of probabilities of information-driven trading get biased downward.

The most striking result is that there appears to be no major change in the estimates of informed trading between late 1999 and the end of 2002. This is interesting, because the PSE (and the Czech Securities Commission) continued their effort to increase transparency and information requirements, manifested by the adoption of several new laws. Given the stability of the probability of informed trading, one can speculate on the apparent rigidity of the PSE. In addition, we found the extent of informed trading was about the same for shares of Česka spořitelna (which left the market) and Erste bank (which controlled about 90 percent of CS, and also started to be listed on the PSE parallel to the Vienna Stock Exchange). There is very little common to those shares except the PSE market makers and therefore, one could speculate and attribute a significant part of information-driven trading to (certain) market makers.

To examine the development of the adverse-selection component of the spread over time, we estimate the model used by Hanousek and Podpiera (2003) for the six stocks with full sample data in 17 two-month windows. The model is briefly described in Appendix II. The estimates of the share of the adverse selection component the interval of ± 2 standard errors are depicted in Figure 2. Although there is some fluctuation in the bi-monthly estimates, all are reasonably close to the average and the standard errors are relatively low. While there is no single pattern to the development of the adverse selection share, none of the stocks exhibits a major decline in the share of the adverse selection component. In fact,

perhaps except for the Česká spořitelna case, the share of the adverse selection component has been increasing rather than decreasing over the sample period.[15]

<INSERT FIGURE 2>

IV. CONCLUSION

This paper studies the functioning of a market-maker trading system (SPAD) at the Prague Stock Exchange since its launch in 1998. We find that the new system has succeeded in increasing the transparency of the market and that it has improved the price discovery function of the exchange by attracting a large portion of order flow to the central market, which forms the price via standard market mechanisms.

We find supporting empirical evidence that investors have benefited from lowered spreads. We also computed estimates of the extent of informed trading for two periods and estimated the share of the adverse-selection component in the spread to assess the importance of informed trading over time and to evaluate the overall impact of a number of measures introduced to improve the functioning of the Czech equity market. However, we do not find any evidence that the extent of informed trading or its impact on the spread decreased over time. Hence, one could interpret the stability of informed trading as showing that there has been little influence of changes in market structure, supervision and enforcement on the extent of informed trading on the PSE.

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[15] See Hanousek and Podpiera (2003) for more detailed discussion of the size of the adverse-selection component, also as related to the extent of informed trading.

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Figure 1: Traded Spread (percent of share price)

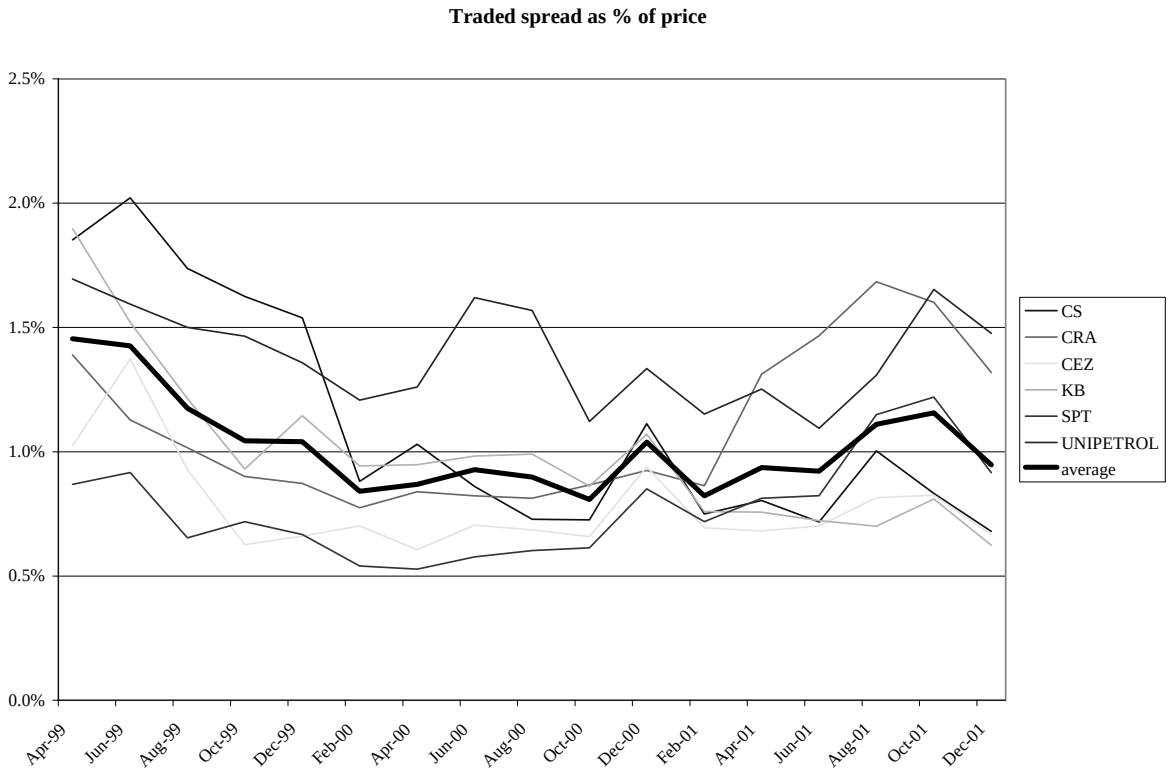
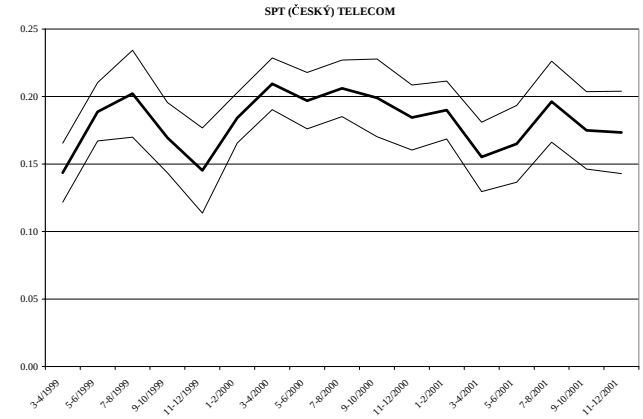
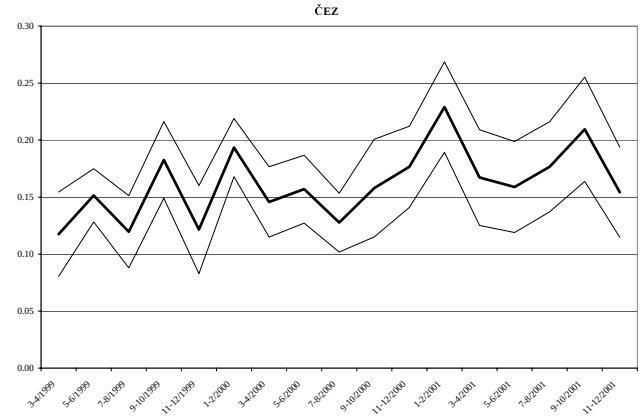
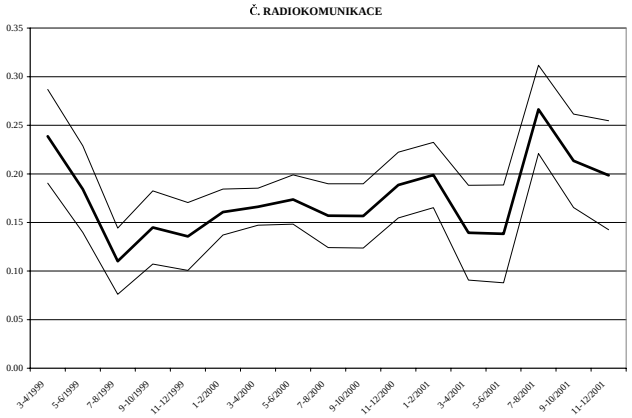
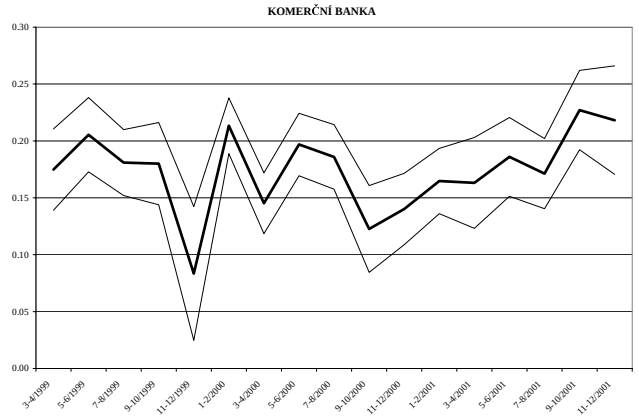


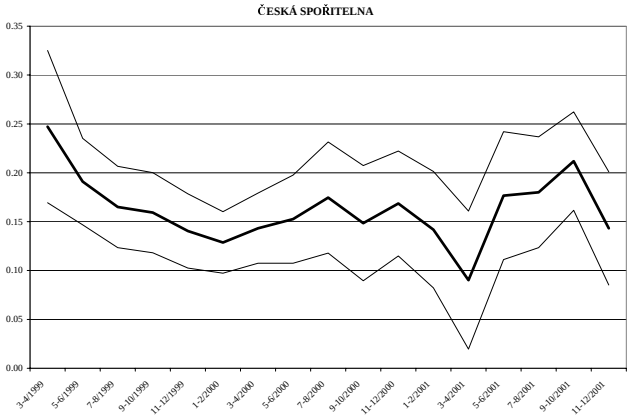
Figure 2: Estimates of the Share of Adverse Selection (α) Using Two-month Windows of Data (interval of ± 2 standard errors also shown)











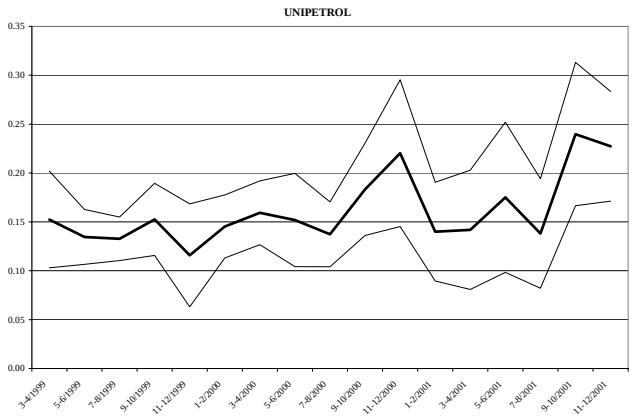


Table 1: Trading Volumes by Market Segments (shares and unit certificates)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Main Market (billion CZK), of which				**149,8**	**197,9**	**123,6**	**136,6**	**213,7**	**109,8**	**174,7**
Central Market				14,7	14,1	66,0	128,5	210,8	102,9	63,4
Direct and Block Trades				135,1	183,8	57,6	8,1	2,9	7,0	111,3
in %										
Central Market				9,8%	7,1%	53,4%	94,1%	98,6%	93,7%	36,3%
Direct and Block Trades				90,2%	92,9%	46,6%	5,9%	1,4%	6,3%	63,7%
Secondary Market (billion CZK), of which				**36,6**	**19,1**	**33,3**	**21,5**	**45,8**	**14,2**	**6,6**
Central Market				3,1	1,9	3,5	12,6	33,8	11,5	3,1
Direct and Block Trades				33,5	17,2	29,8	9,0	12,1	2,7	3,5
in %										
Central Market				8,5%	10,1%	10,5%	58,4%	73,7%	81,2%	47,1%
Direct and Block Trades				91,5%	89,9%	89,5%	41,6%	26,3%	18,8%	52,9%
Free Market (billion CZK), of which				**63,5**	**29,3**	**15,7**	**5,3**	**4,6**	**4,7**	**16,1**
Central Market				10,9	6,0	2,5	1,1	1,3	4,5	5,5
Direct and Block Trades				52,6	23,3	13,2	4,2	3,3	0,3	10,6
in %										
Central Market				17,1%	20,4%	15,9%	21,4%	27,5%	94,2%	33,9%
Direct and Block Trades				82,9%	79,6%	84,1%	78,6%	72,5%	5,8%	66,1%
Total (billion CZK)	**9,0**	**62,0**	**195,4**	**249,9**	**246,3**	**172,6**	**163,5**	**264,1**	**128,8**	**197,4**
Central Market	2	16	22	28,7	22,0	72,0	142,2	245,8	118,9	72,0
Direct and Block Trades	7	46	173,4	221,3	224,3	100,6	21,2	18,3	9,9	125,4
in %										
Central Market	22,2%	25,8%	11,3%	11,5%	8,9%	41,7%	87,0%	93,1%	92,3%	36,5%
Direct and Block Trades	77,8%	74,2%	88,7%	88,5%	91,1%	58,3%	13,0%	6,9%	7,7%	63,5%

Source: Prague Stock Exchange and authors' calculations.

Table 2: Basic Characteristics of the Samples

Period 1 (August to November 1999)

Stock	Market Cap.	Trading Lot (number of shares)	Daily Turnover (mn CZK)	Daily Number of Trades	Avg. Spread* (CZK)	Avg. Spread* (percent)	Number of market makers
ČESKÉ RADIOKOMUNIKACE	36,2	1000	43,0	26,0	16.2	1.4%	13
ČESKÁ SPOŘITELNA	11,6	10000	40,0	19,0	4,10	2.3%	11
SPT TELECOM	126,5	10000	188,0	33,0	5,10	0.9%	14
ČEZ	50,2	20000	79,0	32,0	0,90	1.0%	15
IPS	1,9	5000	4,0	4,0	3,70	2.7%	11
KOMERČNÍ BANKA	17,2	3000	74,0	23,0	12.1	1.3%	12
RIF	12,7	1000	12,0	4,0	10.7	0.8%	10
UNIPETROL	10,9	20000	66,0	27,0	1,20	2.0%	13

Period 2 (October to December 2002)

Stock	Market Cap.	Trading Lot (number of shares)	Daily Turnover (mn CZK)	Daily Number of Trades	Avg. Spread* (CZK)	Avg. Spread* (percent)	Number of market makers
ČESKÉ RADIOKOMUNIKACE	5,8	3000	7,024	8,1	6,48	3,38	6
ERSTE BANK (replacing ČESKÁ SPOŘITELNA)	120,1	500	28,02	23,9	13,22	0,73	6
SPT TELECOM	78,8	5000	61,89	34,6	3,87	1,57	7
ČEZ	54,8	20000	98,23	38,2	0,9	0,98	7
IPS							
KOMERČNÍ BANKA	79,0	2000	231,1	48,4	13,1	0,69	8
RIF							
UNIPETROL	6,3	20000	7,976	8,6	0,82	2,38	7
Tabák (PHILIP MORRIS ČR)	21,3	200	38,86	14,8	133,13	1,18	7

Source: Prague Stock Exchange and authors' computation. * Posted spread (the difference between best bid and best ask prices).

Table 3: Estimates of the Extent of Informed Trading

Company	Oct-Dec 2002					Aug-Nov 1999 1/
	α	**δ**	**ε**	**μ**	**Prob(inf)**	**Prob(inf)**
Č. RADIOKOMUNIKACE	0.23	0.76	3.19	11.25	**0.29**	**0.25**
	(0.07)	(0.14)	(0.12)	(0.89)	**(0.07)**	**(0.04)**
ČESKÝ TELECOM	0.48	0.41	11.96	23.33	**0.32**	**0.28**
	(0.08)	(0.10)	(0.19)	(0.68)	**(0.04)**	**(0.04)**
ČEZ	0.48	0.66	12.92	27.28	**0.34**	**0.32**
	(0.08)	(0.09)	(0.19)	(0.64)	**(0.04)**	**(0.03)**
ERSTE BANK (bought ČESKA SPOŘITELNA)2/	0.36	0.57	8.71	19.32	**0.28**	**0.31**
	(0.08)	(0.12)	(0.18)	(0.80)	**(0.05)**	**(0.05)**
KOMERČNÍ BANKA	0.45	0.39	18.75	26.39	**0.24**	**0.26**
	(0.08)	(0.10)	(0.25)	(0.82)	**(0.03)**	**(0.05)**
PHILIP MORRIS ČR	0.48	0.73	5.21	11.22	**0.34**	**...**
	(0.09)	(0.10)	(0.15)	(0.64)	**(0.05)**	**...**
UNIPETROL	0.32	0.85	3.22	8.51	**0.30**	**0.30**
	(0.08)	(0.13)	(0.14)	(1.18)	**(0.06)**	**(0.07)**
Average	0.40	0.62	9.14	18.19	**0.30**	**0.32**

Note: Standard errors in parentheses below estimates.

1/ As estimated in Hanousek and Podpiera (2002).

2/ Reference period August-November is done for Česká spořitelna, while period October-December refer to Erste Bank. We make this link because in the second period Česká spořitelna left the PSE and its owner Erste Bank started listing on the PSE, so we linked original estimates of Česká spořitelna to those of the Erste bank in the later period.

APPENDIX I

Brief Description of Easley et al. (1996) model

Potentially informed and uninformed traders trade a risky asset with a competitive risk-neutral market maker. Time is split into separate trading days and is continuous within each trading day. Before each trading day begins, nature determines whether an information event that influences the value of the asset occurs. These independently distributed information events occur with probability α and are good news with probability 1- δ and bad news with probability δ. Naturally, the asset has a higher value when good news is coming to the market and a lower value for bad news. The news is fully realized by the traders at the end of each day. In this sense, the days are separated.

Both traders, those who observed no signal and those who did, arrive at the market. Their arrival rates are independent Poisson processes. The arrival rate of uninformed buyers and uninformed sellers is denoted by ε. When an information event occurs, informed traders begin to arrive at rate μ; this also holds for informed sellers, whose arrival is motivated by bad news, and informed buyers, who are attracted by good news. The probability of observing a given number of buys (B) and sells (S) given a vector of parameters θ = (α δ ε μ) can be expressed as

$$L((B,S)\,|\,\theta) = (1-\alpha) * e^{-\varepsilon T} \frac{(\varepsilon T)^B}{B!} e^{-\varepsilon T} \frac{(\varepsilon T)^S}{S!} + \alpha\delta * e^{-\varepsilon T} \frac{(\varepsilon T)^B}{B!} e^{-(\mu+\varepsilon)T} \frac{[(\varepsilon+\mu)T]^S}{S!} +$$

$$+ \alpha(1-\delta) * e^{-(\mu+\varepsilon)T} \frac{[(\varepsilon+\mu)T]^B}{B!} e^{-\varepsilon T} \frac{(\varepsilon T)^S}{S!} \quad . \qquad (2)$$

The first term of the probability denotes an “uneventful day”. The second term designates a “bad event day” and the last term a “good event day”. The likelihood function

(2) takes its particular form due to the assumption of independent Poisson processes driving the arrival of traders. The difference among the three expressions lies in the arrival rates of buyers and sellers; and yet, although we can observe these rates, we cannot say whether some traders saw a signal or not. In fact, only the order flow, that is, the number of buys and sells, is used to draw inferences about the extent of informed trading in this model. Since days are independent, the probability of observing a series of buys and sells is the product of the probability for individual days:

$$L(M \mid \theta) = \prod_{i=1}^{I} L(\theta \mid B_i, S_i) \qquad for\ M = (B_i, S_i)_{i=1}^{I}. \tag{3}$$

Given the data on the frequency of buy and sell orders, maximizing the likelihood expression above will yield the estimates of the four models' key parameters (α δ ε μ). Even though we do not observe the order flow directly, we can conclude from the transaction data which trades were buyer-initiated and which were seller-initiated. We use the simple rule that trades occurring above the quote midpoint, that is, above the average of best bid and ask quotes, are considered buys, and those below the midpoint are coded as sells.

Since the parameters of the model describe the arrival rates of informed and uninformed traders and express the probability that an information event will occur, their estimates can be used to assess the probability that a transaction will be information-based. The probability of an informed trade is expressed as:

$$\Pr(\text{inf}) = \frac{\alpha\mu}{\alpha\mu + 2\varepsilon} \tag{4}$$

This expression compares the expected arrival of informed traders with the expected arrival of all traders. Thus, if it is more probable that an information event occurs and that the arrival rate of the informed traders is greater than that of the uninformed ones, then it is also more likely that a trade is motivated by knowledge of information unknown to all market participants.

Estimation issues

For the estimation we used the likelihood function for the structural model derived in (3). This likelihood function has been maximized, conditional on trade data for a given stock, to obtain estimates of the trade process and information flow for each stock traded in SPAD during the period studied. The probability parameters α and δ were restricted to [0,1]. The arrival-rate parameters ε and μ were restricted to $(0, \infty)$ by a logarithmic transformation. The re-parameterized likelihood function was then maximized using the ML procedure of the TSP 4.5 package. Standard errors for the economic parameter estimates were calculated from the asymptotic distribution of the unrestricted parameters using the delta method.

APPENDIX II

Brief Description of the model used by Hanousek and Podpiera (2003)

We create a binary variable (denoted as PRESS) to indicate whether a particular trade happened in a period of selling or buying pressure. We take a moving window of ten trades prior to the particular trade and, given the number of sells and buys, determine whether there was trading pressure.[16] Further, we assume as do Huang and Stoll (1997) that the traded spread is constant and therefore,

$$P_t - M_t = S/2*Q_t + \eta_t, \qquad (1)$$

where S is the constant traded spread, P_t is the transaction price at time t, M_t is the quote midpoint (average between best bid and ask quotes at the time of trade) at time t, and Q_t is the trade indicator variable, which equals 1 if the trade is a buy, -1 if it is a sell, and 0 if it occurs exactly at the midpoint. We assume that the error term $\boldsymbol{\eta}$ has zero mean conditional on Q.

As in Huang and Stoll (1997), the unobservable fundamental value of the security at time t, $V_{t,}$ is driven by new information in the most recent trade (from time t-1) as indicated by the trade indicator variable Q_t and by several additional characteristics of the trade:

$$V_t = V_{t-1} + \alpha*S/2* Q_{t-1} + \delta*CROSS_t + \varepsilon_t .$$

The variable CROSS indicates whether the trade was a so-called cross trade, that is, a trade between the dealer's own accounting book and that of his client. Such trades naturally

[16] We have estimated the model with three different levels for this variable, requiring the cumulative variable to exceed four, six and eight sells or buys, but we report only estimates for the definition with six buys or sells here. For more details see Hanousek and Podpiera (2003).

do not originate in the SPAD system, but they must be reported so that the market is aware of the order flow. Such trades might be viewed by the market as having a different information value from normal trades. We assume that the error term ε has zero mean conditional on the right-hand side variables.

The actual quotes that we observe are influenced by inventory effects and we assume that inventory matters only when there is significant buying or selling pressure. Thus, the quote midpoint M_t is given by

$$M_t = V_t + \sum_{i=0}^{t-1} \beta \frac{S}{2} Q_i PRESS_i$$

.

Taking first differences and substituting for V_t yields

$$\Delta M_t = \alpha * S/2 * Q_{t-1} + \beta * S/2 * Q_{t-1} * PRESS_{t-1} + \delta * CROSS_t + \varepsilon_t. \quad (2)$$

We estimate equations (1) and (2) simultaneously to obtain the estimates of α, β, δ, and S/2. We choose the generalized method of moments since it imposes very weak distributional assumptions and allows us to account for autocorrelation and heteroscedasticity.