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THE IMPACT OF AUTOMATION ON LIQUIDITY, VOLATILITY, STOCK RETURNS AND EFFICIENCY: EVIDENCE FROM THE TUNISIAN STOCK MARKET

Olfa Benouda Sioud and Dorra Mezzez Hmaied

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ECONOMIC RESEARCH FORUM
منتدى البحوث الاقتصادية
FOR THE ARAB COUNTRIES, IRAN & TURKEY

7 Boulos Hanna St. Dokki, Cairo, Egypt
Tel: (202) 3370810 – (202) 7485553 – (202) 7602882
Fax: (202) 7616042. Email: erf@idsc.net.eg. Website: http://www.erf.org.eg

Abstract

This paper studies the impact of Tunis stock exchange automation on liquidity, volatility and stock price behavior. By the end of 1996, securities listed on the Tunis stock exchange were transferred gradually from a manual trading system to an automated trading, in continuous for the most liquid values and by fixing for the least liquid values. Examination of 20 securities shows an improvement of stock's liquidity. In addition, the transfer was associated with negative abnormal returns but no clear effect has been observed on volatility and pricing error.

1. Introduction

The development of the economies of developing countries was for a long time hindered by the insufficiency of financing. Indeed, their financial systems essentially based on the banking sector, no longer filled the need of firms that had to face more and more menacing international competition with the liberalization policy adopted by most of these countries.

In order to stimulate their financial markets and to favor the creation of new sources of financing, some of these countries decided to undertake reforms to improve their market microstructure, taking into account international norms and experiences of major stock exchanges.

Several stock exchanges decided to automate their trading systems in order to take advantage of existing technology (Black (1971). This wave of reforms concerned also emerging markets such as markets of Israel in 1987 (Amihud, Mendelson & Lauterbach (1997), Singapore in 1989 (Naidu & Rozeff (1994)) and Morocco in 1998 (Derrabi (1998)) which introduced change in their trading systems in order to attract order flows and increase liquidity through improved market transparency and enhanced quality of execution.

In 1996, the Tunis stock market (Bourse des Valeurs Mobilières de Tunis) computerized its trading system and eliminated the traditional trading floor on which brokers exchanged securities.

This paper examines the effects of changing to automated trading on market characteristics such as liquidity, volatility, stock returns and efficiency. It attempts to evaluate the benefits of improving the quality of the trading mechanism and will be helpful to stock exchanges thinking of making changes in their trading methods.

The first section provides a brief description of the Tunis stock market and its trading mechanism. The second section reviews the literature on the impact of change in trading systems. The third section presents our empirical study: the data and the methodology adopted as well as the interpretation of the results. Finally, the conclusion sums up our results and their implications.

2. Presentation of the Tunis Stock Market and its Trading Systems

Different measures undertaken from 1989 to 1994 stimulated the development of the stock market and led to an important increase of the investor demand. Indeed, the volume of exchange increased from 68 million dinars in 1990 to 626 million dinars in 1996. However, this demand was not accompanied by an equivalent increase in the stock offer. This ensued an ascending movement of stock prices. So, the Tunis stock market during five successive years displayed a rise in its index from 199 in 1992 to 634 at the end of 1995.

In the absence of financial information and a real animation of the market, this speculative bubble has been sustained by a mimetic behavior of small investors that dominated the market. Table 1 presents certain key figures related to the evolution of the Tunis stock exchange. From 1996, there has been an adjustment translated into a drop in stock prices. The BVMT index recorded a decrease of 10 percent in 1996, followed by a second decrease of 20 percent in 1997.

Faced with such a situation, the BVMT decided to modernize its microstructure and introduced an automated trading system: the SUPERCAC UNIX developed by EURONEXT. Securities listed on the BVMT were gradually transferred from the traditional system (quotation on panels) to the new electronic trading system.

2.1 The Quotation on Panels

Prior to October 1996, the system was based on a continuous trading. All listed stocks were traded once a day from 10:00 a.m. to 11:30 a.m. by a written confrontation on panels reserved to each security. The panel is separated into two columns: the left (right) column is reserved to sell (buy) orders.

When writing down an order on the panel, the broker specifies its reference, the quantity and the price offered. Brokers cannot write on the same column at the same time. Negotiations are competitive, the buy (sell) order with the highest (lowest) price has priority in execution. In addition, orders at the same price are submitted to time priority.

2.2 The Automated Trading System

From October 1996 until July 1997, a system based on an electronic negotiation replaced the manual quotation on panels progressively.

The automated trading system started in October 25, 1996. This was preceded by a simulation phase (from March to June 1996) that enabled stock operators to be familiar with the new trading system while presenting a demonstration platform composed of stations of negotiation and a server directly connected to computers of the Paris stock market. From July to September 1996, there was a phase of preparation with the installation of the stations of negotiation and all the necessary infrastructure. September and October 1996 were devoted to brokers' training.

The BVMT is an order-driven market. It uses a centralized computer limit order book system. Every broker has a terminal to enter orders in the order book and a telephone to communicate with its headquarters and possibly receive other order flows. The highest limit price of all buy orders for a particular stock is the best bid price for the stock, and the lowest limit price of all sell orders for a particular stock is the best ask price for the stock.

The BVMT operate a continuous market for frequently traded securities and a call auction (fixing) for infrequently traded securities. Phases of pre-opening and opening are common to the two types of quotation in continuous and by fixing.

During the pre-opening phase (from 9:00 a.m. to 10:00 a.m.), buy and sell orders are entered and accumulated in the order book without permitting transactions. However, the convergence process of prices to their equilibrium levels is open and a theoretical opening price is displayed systematically. This price must maximize the number of stocks traded. If this price is not unique, the system chooses the one that minimizes the number of securities non served. Finally, if this criterion is not discriminative, the price applied verifies the two former criteria and is the closest to the last price. During this phase, prices are displayed and followed-up in real time and orders can either be modified or cancelled.

The opening phase takes place by fixing at 10:00 a.m. It is no more possible to cancel or to modify previous orders and all transactions are executed at a single price simultaneously.

For securities in the "fixing" category:

- a second fixing takes place at 10:15 a.m. for securities which have not be exchanged at the first fixing,
- and a last fixing is intended at 10:45 a.m. for all securities.

The continuous market operates from 10:00 a.m. to 11:00 a.m. When a new order is entered in the system, the computer checks the order book. If the order can be matched against existing orders, it is executed. However, it will only be executed if all previous orders have been executed completely (first entered, first served). If not, the order is added to the list of orders already waiting and is assigned price and time priorities, but not transactions volume priority.

The new system has daily price limits of ±3 percent of the previous day's price. When a stock reaches its price limit, trading in this stock is halted for 30 minutes after which new limits (±1,5 percent) are applied.

The electronic system offers many advantages for stockbrokers and permits a better protection for investors. In fact: (i) the order book is observed by all stockbrokers at the same time[1], (ii) the new trading system is managed by a software offering stockbrokers a set of tools and information that facilitate their tasks, (iii) it offers more protection for investors: trade reporting is automated and real time publication is technically feasible, thus investors can check if their orders have been reliably executed.

[1] The five best limit selling and buying orders in the order book are public information.

3. Review of the Literature

An abundant theoretical and empirical literature has been interested in stock market microstructure and particularly in the change of the trading mechanism. The literature advances the reasons why this change could influence aspects of trading such as liquidity, stock behavior, volatility and market efficiency. We discuss, in this section, the impact of temporal consolidation of orders, automated trading, market transparency and duration of the trading session on such aspects.

3.1Temporal Consolidation of Orders in the Fixing System

Mendelson (1985) shows how increasing the number of participants in the auction increases price precision. In fact, a large number of participants take part in the determination of the equilibrium price, which lowers volatility and pricing error[2].

Schwartz (1991) suggests also that call auction has a positive impact on liquidity, volatility and pricing error. The call auction system is based on a temporal consolidation of orders and permits the determination of a single price for all transactions, and incites the investors to post limit orders, thus improving market liquidity.

Amihud & Mandelson (1987) and Stoll &Whaley (1990) find that the volatility of stocks traded on the NYSE, is higher at the opening (call auction) than in the closing transaction (continuous trading). The higher volatility at the opening of the trading session is not related to the trading method. In fact, authors explain this result by the non-availability of all the order book and the impossibility for investors to adjust their positions before the opening becomes effective. The higher volatility at the opening is also due to the particular practices of the NYSE.

Amihud, Mandelson & Murgia (1990) study the impact of stock market microstructure on return volatility and on the value discovery process in the Milan stock market. The trading mechanism employed is a call market, which is usually preceded and followed by trading in a continuous market. They find that the opening transaction in the continuous market has the highest volatility, and that opening the market with the call transaction seems to produce relatively lower volatility. In the closing transaction, investors correct perceived errors or noise in the prices set at the call.

Otherwise, Amihud and Mandelson (1991) note on the Tokyo stock market, which employs a clearing procedure at the opening of each of the two daily continuous trading sessions, that the volatility is lower at the opening of the second session. They explain the important volatility at the daily opening transaction by the preceding non-trading period.

[2] Pricing error: the difference between the equilibrium price and the transaction price.

3.2 Automation of the Trading System

Some authors affirm that automated trading can have a negative effect on liquidity when transactions are often the result of human interactions. Biais et al. (1997) suggest that automation can lead liquidity to decrease because it doesn't allow a direct negotiation between traders for important transactions and doesn't allow them therefore to preserve a certain control on trading conditions.

In contrast, Pirrong (1996) has shown that automated exchanges can be deeper and more liquid than open outcry exchanges.

Naidu & Rozeff (1994) note an increase of volatility and liquidity as well as an improvement in efficiency following the automation of the Singapore stock exchange. They advance that automation speeds up the dissemination of prices, making it likely that volatility will increase, especially when information is hitting the market. The increased speed with which prices and trading volume are available incites investors likely to trade to exploit the published information, which is likely to improve market efficiency.

Derrabi (1998) was interested in the change of the Moroccan market microstructure. The automated trading by fixing produced a significant and permanent increase of prices. The fixing system also permits efficiency improvement and lower volatility but no significant impact has been noted for stocks traded in continuous.

3.3 Market Transparency

Biais (1993) compares centralized and fragmented markets. In centralized markets, participants observe prices and transactions, and take them into account in their strategies. In fragmented markets, transactions are the outcome of bilateral negotiations that other market participants cannot observe. Consequently, information about market conditions is more readily available in centralized markets than in fragmented markets. The liquidity suppliers (i.e. market makers, dealers…) are shown to take advantage of the lack of transparency of fragmented markets.

Pagano and Roell (1996) compare liquidity and price formation processes in several trading systems with different degrees of transparency. Transparency is defined as the possibility to observe the size and the direction of the order flow. They suggest that greater transparency in the trading process improves market liquidity by reducing opportunities for taking advantage of less informed participants. Then, spread, volatility and pricing error are likely to decrease. Nevertheless, investors can prefer in certain cases a less transparent system to take advantage of their private information.

Harris (1996) supports that markets that are too transparent lead informed investors to quit the market because if they reveal their positions, they run the risk that this information will be used on their depends.

3.4 The Duration of the Trading Session

Schwartz (1991) stipulates that a longer trading session can lead transaction costs to decrease therefore increasing liquidity. Otherwise, Gillet (1994) suggests that a longer trading session may produce higher volatility when the market is not sufficiently liquid.

Amihud, Mendelson & Lauterbach (1997) examine the effects of stock transfer on the Tel Aviv stock exchange from a call auction to a new mechanism (a call auction followed by iterated continuous trading sessions) on stock prices and trading volume. Stocks traded under the new trading method enjoyed significant and permanent price increase due to improvement of market microstructure. Otherwise, stock liquidity increased following the decrease of transfer and pricing error, thus improving market efficiency.

4. Methodology and Empirical Results

The present paper studies the impact of the automated system adopted by the Tunis stock market on liquidity, the behavior of stock returns, volatility and pricing error. The transfer of stocks to the new trading system represents a pure market microstructure event since the decision was made by the stock exchange authorities and not by the companies' management.

4.1 The Data

38 Stocks were listed on the Tunis stock market before automation. We selected heavily traded stocks[3] over the period examined which resulted in a sample of 20 stocks (1 stock transferred to continuous trading and 19 stocks transferred to the fixing system).

The data used in this study are provided by the BVMT over the period January 2, 1995-December 31,1998: dates of transfer to the new trading system, daily closing prices[4], volumes of trading, amounts and dates of dividends paid as well as market index returns.

The event being the transfer of stocks to the automated trading system, the data are centered around the date of transfer. Thus, week 0 is the week of trading resumption after an interruption noted for the majority of values, and date -1 is the last trading week before the transfer. Table 2 presents the sample and periods of trading interruption preceding and following the transfer.

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[3] Heavily traded stocks are stocks for which daily trading frequency is superior or equal to 70 percent.

[4] We adjusted prices for splits and equity issues.

A period of trading interruption has been noted for the majority of stocks before and after the transfer. It is on average 17 trading days after the transfer, varying from 1 to 49 days. However, the period of interruption before the transfer is rather significant exceeding 2 months for 35 percent of our sample and reaching 114 trading days for 3 securities.

According to some brokers, interruptions before the transfer were due to lack of transactions for most of the securities. Indeed, deflation of the speculative bubble observed in 1994 and 1995 incited investors to sell stocks in order to limit their losses. By fear of a fast downfall of the stock market, authorities decided to adopt a corrective measure: from March 1995 until October 1996, stock prices could only change following a minimum transactions amount of 50 000 DT (then 30 000 DT and finally 5 000 DT). Unfortunately, this measure complicated the situation even more and blocked transactions.

However, the absence of trading observed for certain stocks following their transfer could be due to two reasons:

- The lack of liquidity for several stocks and the absence in certain cases of compatible limits;
- For several securities, prices were lower than the price limits authorized, which led to halts of quotation.

4.2 Liquidity

Theoretically, the trading volume of a given security is an increasing function of its liquidity, other things being equal. Thus, an increase in the trading volume of a stock after its transfer to the new trading system reflects an increase in its liquidity.

In our case, we suppose that temporal consolidation of orders and better transparency ensued better liquidity. However, the automated trading system and the absence of direct negotiations between participants could reduce market liquidity.

Liquidity in the BVMT cannot be measured by bid-ask spreads. While it is possible to impute a bid-ask spread from the best limit prices of the buy and sell orders, data are unavailable. Therefore the measure of liquidity used is the trading volume[5].

[5] Comparing several measures of liquidity, Jousset (1992) concludes that the more adequate and most operational measure is the trading volume.

Two empirical tests are conducted. First, we calculated the relative volume of each stock VR_{it} for each event week t, $t \in [-50, +50]$[6].

$$VR_{it} = \frac{\log(V_{it})}{\log(V_{Mt})} \quad (1)$$

V_{it} is the cumulative stock's volume on the week t,

V_{Mt} is the cumulative market volume on the week t.

Then, the relative volume is averaged across the 20 stocks of the sample, for every week t.

$$VR_{mt} = \frac{1}{20}\sum_{i=1}^{N} VR_{it} \quad (2)$$

The resulting time series of 101 observations is presented in figure 1. As shown in Fig.1, the transfer of stocks to the automated system is associated with an important increase in their trading volumes. The mean relative volume was 0.58 over event weeks [-50, -1] compared with 0,72 over event weeks [0, +50]. The difference between the two periods is significant at the 1 level (t-statistic = 16.95)[7]. After the transfer, the increase of the trading volume continues until the tenth week without declining, which sustains that this increase is not temporary. In fact, BVMT reports noted that the trading volume for the last quarter of 1996 reached 87 million dinars against an average quarterly volume of 62 million dinars for the first three quarters of 1996.

In the second test, we define the change in the relative volume for each security i as:

$$\Delta VR_i = VR_i(a) - VR_i(b) \quad (3)$$

VR_i is the average weekly relative volume on stock i, and the subscripts indicate before (b) and after the transfer (a).

The results presented in table 3 show that the change in the relative volume was positive for 90 percent of the transferred stocks; its mean was 0,145 (t-statistic=4,21; sign test =3,58).

The transfer to the automated trading favored the fluidity of trading. This confirms our hypothesis that temporal consolidation of orders and better transparency of the market have a positive impact on liquidity.

[6] Mai et Tchemeni (1995) show that logarithmic transformations of trading measures improve the normality of series.

[7] We use means equality test.

4.3 The Behavior of Stock Price

We advance that improving market microstructure under the electronic trading would have a positive effect on the prices of transferred stocks. Otherwise, the improvement of liquidity noted in the previous section and a better transparency of the market should result in lower returns required by investors and therefore a rise in prices.

We tested this hypothesis by conducting an event study of the transferred stocks (Brown and Warner, 1980). This methodology enables us to discern the effect of the transfer on the behavior of stock returns, by detecting some abnormal returns after the realization of the event.

Weekly returns are calculated on the basis of adjusted prices according to the following formula:

$$R_{it} = \frac{P_{it} - P_{it-1} + D_{it}}{P_{it}} \qquad (4)$$

Rit is the return on stock i on week t, Pit is the weekly closing price of stock i on week t, Dit is the dividend paid on week t.

The market model is estimated over weeks [+11, +45] as follows:

$$R_{it} = \alpha_i + \beta_i R_{Mt} + \varepsilon_{it} \qquad (5)$$

R_{it} is the return on stock i on week t; R_{Mt} is the return on market index on week t; α_i et β_i are constant coefficients and □it are the residuals.

Then, we calculated the abnormal return for each week t in the event window, weeks [-10, +10]:

$$AR_{it} = R_{it} - (\hat{\alpha}_i + \hat{\beta}_i R_{Mt}) \qquad (6)$$

The parameters α et β were estimated by the market model. Then we averaged abnormal returns across all stocks at each event week:

$$AR_t = \frac{1}{N}\sum_{i=1}^{N} AR_{it} \qquad (7)$$

N is the number of securities in our sample (20 stocks).

The negative average abnormal return observed at the trading resumption of -14,97 percent (t-statistic =1.85, sign test = 4.47), points out a significant fall in prices following the transfer. This stock's decrease is contrary to our hypothesis that foresees prices increase with the improvement of the market trading system.

Figure 2. illustrates the evolution of the abnormal returns and the cumulative abnormal returns on the event window. As shown, the impact of the transfer on stock prices is not temporary. In fact, prices had not recovered their initial level in spite of a slight increase at the 4th and 6th weeks

However, the observed fall in prices cannot be considered as a negative reaction of the market to the adoption of the automated trading system. The interpretation of results must be shaded by taking into account that the transfer has coincided with a reversing tendency of the Tunisian stock market.

In fact, as presented in the section four, the deflation of the speculative bubble instituted a panic within investors who hurried to sell their securities. The setting up of conditions by authorities as for the amount of transaction to modify the reference price worsened the situation and dragged a blockage of transactions.

Since the new electronic trading system doesn't impose any constraint as to the amount of transactions, it allowed an unblocking of the situation and especially a correction in prices. This return to normal was an inevitable condition for the resurgence of the financial market.

4.4 The Volatility of Stock Prices

Sato (1992) suggests that under automation, the volatility rises due to overshooting or undershooting because traders using screens do not understand the reasons for price movements, as do traders on a trading floor. Naidu and Rozeff (1994) support that automation has the potential to alter both volatility of stock's returns and the trading volume.

However, Derrabi (1998) notes a decrease in volatility on the Moroccan stock exchange after automation for securities quoted by fixing. He explains this result by the temporal consolidation of orders and the unicity of prices applied in the trading system by fixing, which reduces the impact of every order on the equilibrium price.

The volatility of securities can be defined by fluctuations of stock prices, which can be estimated by the variance or the standard deviation of stock returns. If the change in trading mechanism had no effect on stock volatility, the variance would be the same for the two return series (before and after the transfer).

To conduct this analysis, we exclude the event window in order to alleviate disturbances that accompanied the stock transfer, and we use the F-ratio, which is the ratio of two sample variances with the larger variance in the numerator. Variances are calculated on weekly returns: 35 weeks before and 35 weeks after the event window for every stock i. A significant F-ratio suggests that variances of the samples are unequal. A plus (+) sign indicates the variance has increased after the transfer, while a negative (-) indicates a reduction in the post-listing sample variance.

The standard deviation of stock returns increased meaningfully for 60 percent of the sample (12 stocks). These results suggest that the transfer to the electronic trading didn't have the same impact on volatility for all securities. This may be explained by many factors that had contradictory effects on volatility:

I. The increase in trading volume may increase volatility,

II. Most of our sample (19 securities) were transferred to the fixing system which is based on temporal consolidation of the orders and may reduce volatility,

III. The important fall in prices of transferred stocks disturbed investors and enhanced heterogeneous behaviors, which may increase volatility.

4.5 Trading System and Market Efficiency

The automated trading system offers more transparency and ensures better treatment of information, thus minimizing the noise associated to the determination of prices.

The methodology analyzes the behavior of the market model residuals before and after the transfer to the automated trading mechanism. The decrease of the residual variance after the transfer will be interpreted as a reduction of the pricing error and therefore an improvement of efficiency.

4.5.1 Pricing Error across Stocks

We follows the methodology presented by Amihud and Mendelson (1989) that introduced the Relative Return Dispersion (RRD) based on the variance of returns across securities as a descriptive measure of the efficiency of a trading mechanism. The RRD is defined by:

$$\text{RRD}_t = \frac{1}{20}\sum_{i=1}^{20}\varepsilon_{it}^2 \qquad (8)$$

Where ε_{it} is the market model residual of stock i on event week t. The market model was estimated separately over weeks [-49,-11] before the transfer and [11,45] after.

Figure 3 presenting the behavior of residuals before and after the transfer, shows a slight increase in the RRD. The average RRD passed from 0,057 over weeks [-49,-11] to 0,079 over weeks [11,45].

4.5.2 Pricing Error on Individual Stocks

Our methodology used a test of heteroscedasticity (the conditional variance of the market model residuals is not constant) to detect the change in the residual variance. For each stock i, the market model was estimated separately over weeks [-49,-11] before the transfer and [11,45] after. Then, we calculate the following statistic:

$$F_i = \frac{SCR_1 / T_1 - k}{SCR_2 / T_2 - k}$$

With SCR1 (SCR2): the sum of residuals squares of the market model before (after) the transfer:

- T1 (T2): the number of observations before (after) the transfer;
- k: the number of parameters of the market model (k=2).

Table 6 suggests that the transfer of stocks to the new trading mechanism didn't have a significant impact on pricing errors of individual stocks. In fact, it shows a significant increase (decrease) in the residual variance for 50 percent (10 percent) of our sample.

This result can be explained by heterogeneous behaviors observed on the market after the important stock fall (as presented in section four), which prevented the electronic system from improving market efficiency.

5. Conclusion

In 1996, the Tunisian stock authorities adopted an automated trading mechanism inspired by the CAC system used by the Paris stock market in order to improve market microstructure and to offer investors more protection and transparency. The present paper examines the impact of automation on liquidity, stock returns, volatility and market efficiency.

For most of our sample, an interruption of the quotation has been observed before and after the transfer as a result of the reforms undertaken by the authorities to avoid a fast downfall of the stock market.

Otherwise, our empirical results show:

- A significant abnormal return about -15 percent for all securities of our sample. This decrease reflects stock prices correction with the reversing tendency of the stock market rather than a negative reaction to the improvement of the trading system. Thus, transfer to a new electronic trading system that doesn't impose any constraint on the amount of transactions required to modify reference price, permitted an unblocking of the situation and especially price adjustments.
- An increase in trading volume after transfer of stocks to the new system. The mean trading volume was 0,58 before the transfer compared to 0,72 under the automated trading, reflecting a better liquidity of stocks.

- No significant impact has been detected on volatility. This may be explained by many factors that had contradictory effects on volatility: (i) The increase of the volume transaction may increase volatility, (ii) the temporal consolidation of orders with the quotation by fixing should reduce volatility, (iii) the important fall of stock prices disturb the investors and enhance more heterogeneous behaviors.

- Finally, the new trading mechanism doesn't reduce pricing error and thus doesn't improve market efficiency.

After a period of anarchy, different reforms and more particularly the adoption of the electronic trading mechanism, were an inevitable condition for the restructuring and resurgence of the Tunisian stock market. Our results confirm respectively conclusions of Naidu and Rozeff (1994) and Derrabi (1998) who highlighted the benefits of improving the trading mechanism and thus, may interest stock exchanges thinking of automating their trading systems.

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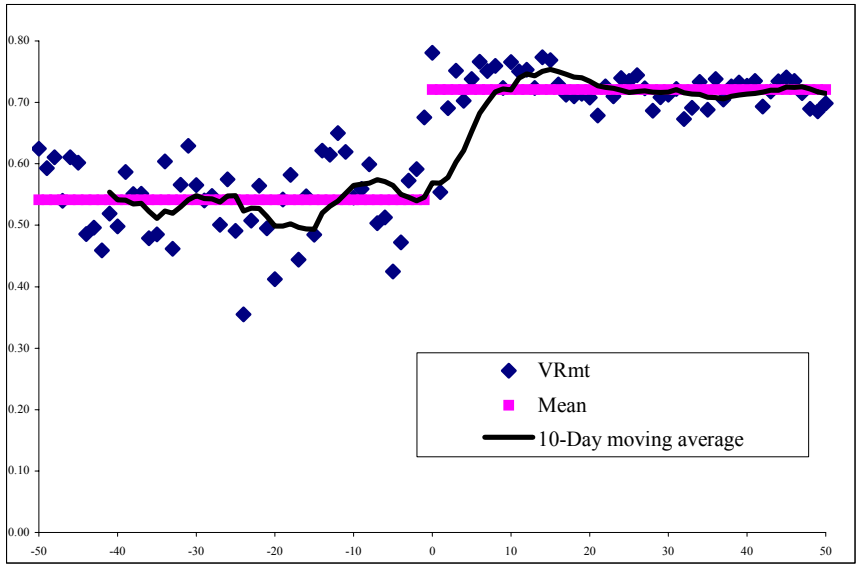
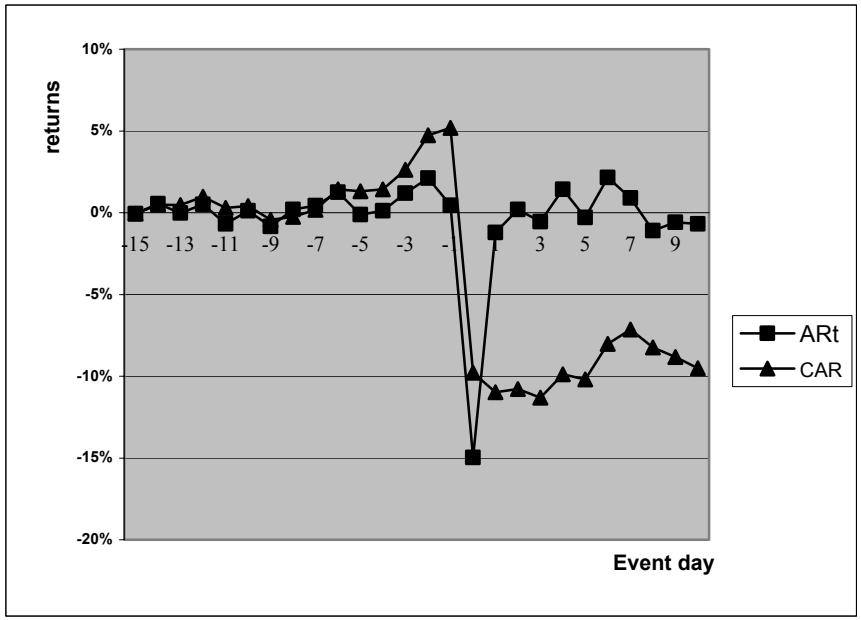
Figure 1: Weekly Relative Volumes



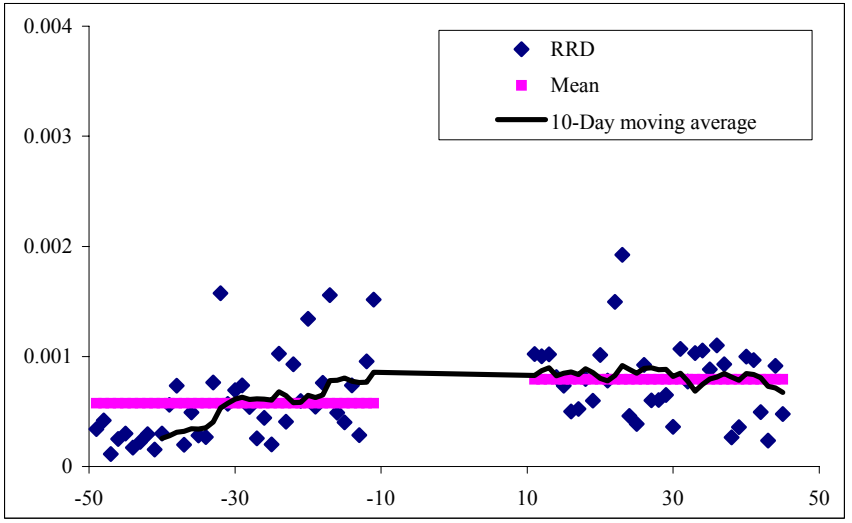
Notes: Weekly relative volumes calculated over event weeks [-50, -1] and [0, 50]. The curved line shows 10-week moving average for the relative volume time series. The two steady lines represent the mean relative volume before and after the transfer**.**

Figure 2: Average Abnormal Returns and Cumulative Average Abnormal Returns.



Notes: This figure depicts the average abnormal returns and cumulative average abnormal returns for the 20 stocks transferred from manual system to electronic system on the Tunis stock exchange. Week 0 is the week of resumption of quotation after an interruption noted for the majority of the stocks. Week -1 is the last week of trading before the transfer.

Figure 3: Relative Return Dispersion "RRD" Before and After the Transfer.



Notes: The curved line shows the10-week moving average of RRD series. The two steady lines represent the mean RRDs over weeks [-49,-11] and [11,45].

Table 1: Evolution of Tunis stock market activity

Years	1992	1993	1994	1995	1996	1997	1998
Capitalization/GDP	5,78%	6,82%	15,97%	23,26%	20,41%	12,59%	10,79%
Transactions Volume /GDP	0,93%	1,10%	3,36%	5,44%	3,28%	2,82%	4,08%
BVMT Index	199	251	507	635	571	455	465
Yearly variation of the index	16%	26%	102%	25%	-10%	-20%	2%
PER	12	12	25	26	23	12	10

Sources: Yearly reports of the Tunis stock exchange

Table 2: Periods of trading interruption preceding and following the transfer

Sample	Interruption preceding the transfer	Interruption succeding the transfer
MONOPRIX	0	37
STE FRIGO BRASS TN	0	6
TUNISAIR	0	12
BQ TUN EMIRAT INV	0	46
SPDIT-SICAF	1	20
ATEL. MECA SAHEL	9	28
BANQUE DU SUD	114	17
BIAT	0	17
BQ HABITAT	3	15
TUN. LEASING	0	22
BT	20	1
UNI BQ COMM & IND	0	3
PLAC DE TUNISIE	2	49
STE. TUN. BANQUE	114	4
BQ NAT. DEV. TOUR.	103	16
BQ NAT. AGRICOLE	114	4
AMEN BANK	46	5
BQ DEV ECO TUN	96	19
ARAB TUN BANK	10	20
TUNINVEST SICAF	99	1
Mean	37	17
Standard deviation	48	14

Notes: *Interruption periods (in trading days).
*Tunisair is the only stock traded in continuous immediately after the transfer.

Table 3: Impact of the transfer on trading volume

Stock	VRi(b)	VRi(a)	ΔVRi
1	0,623	0,723	0,100
2	0,512	0,735	0,223
3	0,840	0,869	0,029
4	0,808	0,797	-0,012
5	0,570	0,651	0,081
6	0,223	0,590	0,367
7	0,734	0,737	0,003
8	0,677	0,829	0,153
9	0,666	0,762	0,095
10	0,263	0,786	0,523
11	0,698	0,794	0,096
12	0,713	0,753	0,040
13	0,593	0,595	0,002
14	0,482	0,619	0,137
15	0,779	0,762	-0,016
16	0,342	0,577	0,235
17	0,643	0,692	0,049
18	0,380	0,703	0,324
19	0,276	0,695	0,419
20	0,751	0,801	0,050
Mean	0,579	0,723	0,145
Standard deviation	0,192	0,083	0,155
ΔVi positive			90%
t-statistic			4,21
Sign test			3,58

Table 4: Impact of the transfer to the electronic trading system on stock prices (weeks [-10, +10])

Event Week	AR_t	t- statistic
-10	0,11%	0,02
-9	-0,84%	-0,34
-8	0,19%	0,09
-7	0,43%	0,16
-6	1,24%	0,35
-5	-0,11%	-0,03
-4	0,12%	0,04
-3	1,19%	0,25
-2	2,11%	0,48
-1	0,45%	0,14
0	**-14,97%**	**-1,85***
1	-1,20%	-0,17
2	0,21%	0,07
3	-0,54%	-0,06
4	1,43%	0,13
5	-0,30%	-0,07
6	2,16%	0,22
7	0,89%	0,20
8	-1,10%	-0,29
9	-0,59%	-0,17
10	-0,69%	-0,38

Notes: * significant at 10% level

Table 5: Impact of the transfer to the new trading system on stock prices volatility. (□i(b), □i(a): standard deviations respectively 35 weeks before and after the event window)

Stock	$\sigma_{i(b)}$	$\sigma_{i(a)}$	F*
1	0,032	0,031	1,03
2	0,044	0,036	1,46
3	0,034	0,020	2,91 (-)
4	0,022	0,053	5.88 (+)
5	0,012	0,072	38.46 (+)
6	0,022	0,048	4.95 (+)
7	0,022	0,033	2.27 (+)
8	0,028	0,046	2.67 (+)
9	0,009	0,020	4.83 (+)
10	0,032	0,013	6,50 (-)
11	0,028	0,032	1.23
12	0,036	0,054	1.12
13	0,022	0,040	3.31 (+)
14	0,020	0,033	2.67 (+)
15	0,023	0,037	2.07 (+)
16	0,010	0,040	15.63 (+)
17	0,039	0,033	1,38
18	0,018	0,039	4.74 (+)
19	0,010	0,023	4.85 (+)
20	0,024	0,027	1.30

Note: σ^2_b et σ^2_a are significantly different at the 5% level . A plus (+) sign indicates the variance has increased after the transfer, while a negative (-) indicates a reduction in the post-listing sample variance.

Table 6: Test of equality of variances of the market model residuals before and after the stock's transfer

Stock	SCR_1	SCR_2	F
1	0,0293	0,0276	0,947
2	0,0151	0,0153	0,877
3	0,0564	0,0313	1,606
4	0,0365	0,0114	2,851*
5	0,0165	0,0647	0,227*
6	0,0047	0,1408	0,029*
7	0,0175	0,0749	0,208*
8	0,0159	0,0259	0,546*
9	0,0295	0,0516	0,510*
10	0,0030	0,0126	0,210*
11	0,0356	0,0053	5,983*
12	0,0220	0,0288	0,682
13	0,0443	0,0390	1,011
14	0,0180	0,0465	0,345*
15	0,0143	0,0221	0,577
16	0,0206	0,0259	0,795
17	0,0028	0,0509	0,055*
18	0,0521	0,0339	1,537
19	0,0101	0,0321	0,281*
20	0,0038	0,0168	0,224*

Notes: * $\sigma^2_{\varepsilon_{ib}}$ et $\sigma^2_{\varepsilon_{ia}}$ are significantly different at the 5% level