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Διπλωματική Εργασία με θέμα:

# Εκτίμηση «*Δικαιωμάτων Ρευστότητας*»: μέτρηση της, κατασκευή υποδείγματος, αποτίμηση με βάση το υπόδειγμα Black-Scholes, πιθανές εφαρμογές τους.

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# Contents

## 1. INTRODUCTION

The primary aim of our paper is to propose a methodology for pricing what is called a "liquidity option." Liquidity options are put options, a listed company gives to its large shareholders, by which it enables them to sell back to the company the amount of shares they possess, in case they decide to liquidate their positions.

In the first place, it seems there is no need or reason for such an option to exist: the investor could as well sell the shares he owns, either in the open market -on the floor of the stock exchange, or in the "upstairs market" where block trades take place, without having second thoughts. And this should be the case with sufficient liquidity in the secondary market.

The existing methods of trading may not guarantee the investor either the immediate execution of his order or the settlement price of it, two issues to which the investor is highly sensitive. Thus, thoughts for creating a derivative that would meet this need for immediate liquidation of a large order at the spot price of the stock began to be expressed.

Today, the notion of liquidity option is somewhat known to the stock markets, but peculiarities to its pricing prevent it from being used. What we are going to do in this paper is to display these peculiarities, as well as build a specific environment in which we will try to price such an option.

In this effort, we should firstly acquaint ourselves with the notion of liquidity and the theoretical model trying to explain the way it emerges. Then, since the price formation process is highly dependent on the settings of the trading mechanism, we are going to present the procedures followed in ASE, in order to get informed of the way settlement prices of transactions are determined. We will analyze the alternative procedures of executing an order, as well as the utility a liquidity option provides to the interested counterparts, and the reasons it may be superior to the other methods. Further, we will make some assumptions, use some empirical measures of liquidity, and try to work out a methodology leading to a price for the option. We will use real data for three listed stocks on ASE, estimate the prices of the liquidity options for these particular stocks, and analyze the empirical results of this process.

The issue of this paper is quite challenging and unusual. Thus, we invite you to a tour to liquidity options, and promise you will enjoy it!

## 2. THEORETICAL MODELS OF LIQUIDITY

It should be remarked, right in the beginning that because liquidity emerges in the market, it highly depends on the structure of the trading mechanism. In this section, we will make a brief revision of the theoretical models related to liquidity, while in the next one, we will discuss in detail the Athens Stock Exchange settings.

The nature of liquidity has troubled scientists for a long time. It is aptly remarked, that liquidity is easily recognized, but not so easily defined. Therefore, there are so many models trying to describe it.

One point of view argues, *liquid markets are those, which accommodate trading with the least effect on price*. Kyle [1985] built a model and worked out a measure of liquidity, $\lambda$, where $\lambda$ measures the order flow needed to move prices by one unit. Instead of writing down the equations of the model, we will discuss its assumptions and findings.

Kyle assumed there is a batch trading mechanism, where one risk neutral market maker observes the aggregate order flow, sets a single price equal to the conditional expected value of the asset given this flow, and clears all trades at this price. In doing so, he assumes an informed trader and some uninformed liquidity traders who submit orders for exogenous reasons to the model.

An important assumption is that the market maker does not see or care about individual orders, but rather sets a market-clearing price given the aggregate net order flow. Under these circumstances, the bid-ask spread, quoted by a real world market maker, is not allowed for, which is a clear drawback of the model.

Kyle presents the equilibrium strategies of both the market maker and the informed trader, and ends up suggesting the variable $\lambda$ reflects how much the market maker adjusts the price to reflect the information content of trades. A disadvantage of the model is the calculation of $\lambda$ uses parameters which cannot be estimated satisfactorily in the real world, such as the information about the variance of the *ex post* liquidation value of a stock the informed trader receives, as well as, the variance of the uninformed traders' order flow.

Kyle also assumes the market maker's price is linear in the aggregate order flow. One way to interpret this pricing relation is that large volume results in a 'worse' price, but not necessarily an increasingly worse price. For example, if the market maker faces a large negative trade imbalance (all the traders go short the stock) he may end up setting a negative price, which obviously cannot be the case in the real world. So this linear pricing role can, at best, be used as an approximation of the actual price formulation process.

Later, Kyle extended its model to consider the sequential-auction and the continuous auction frameworks. The equations become more complex but the intuition remains the same, and the model suffers of the same drawbacks. Many scientists worked on the Kyle's models and extended them. Most significant is the contribution of Admati and Pfleiderer [1988] who talk about many informed and uninformed traders acting strategically and timing their orders. Moreover, the trading day is divided to T intervals of time. Nonetheless, they hold the assumption of the batching order mechanism, so the market maker sets the clearing price after he has seen the net order flow in each time interval.

They end up with a more complex equation for λ, where we can distinguish an important property: λ is decreasing in the number of the informed traders. Hence, as the number of the informed traders increases, order flow has less effect on prices. This reflects the ability of deepest markets to accommodate informed trading with less effect on price. Interpreting this argument, we may assume *a market to be quite liquid when large orders that can be information-initiated have a relatively little effect on the spot price of the stock.* This consideration is very significant and is highly respected in the real world.

Although the Admati and Pfleiderer model, as the rest of the models belonging in this family, is based on restrictive and unrealistic assumptions, such as the batching order mechanism with a single market clearing price and the elimination of bid-ask quotes, the above argument is often used in practice as an empirical criterion for characterizing the status of liquidity in market. Since the parameters for the estimation of λ are very difficult, if not impossible, to be estimated, the above consideration is proposed as an alternative to the λ estimator.

The next family of models is the one adopting the bid-ask spread the market maker quotes as a measure of liquidity. Under this point of view, *the markets with smaller spreads are more liquid.*

Assuming the arrival time of sell and buy orders is Poisson distributed with a stationary arrival rate function, and the market maker's primary concern is to maximize expected profit per unit of time, while at the same time to avoid going bankrupt (in the case that he runs out of either cash or stock), Garman [1976] builds a rather stylized framework. The market maker is assumed to be a monopolist with an infinite horizon. Garman concludes that the market maker should set a lower price when he buys stock and a higher one when he sells it, in order to stay alive as long as possible. Nevertheless, he argues the spread does not protect absolutely the market maker from failure; on the contrary, the specialist always faces positive failure probabilities.

In the question why there are two prices quoted, a bid (where the market maker buys one unit of stock) and an ask (where the market maker sells one unit of stock) there has been a variety of answers according to the assumptions of the models the researchers have used. Amihud, Mendelson and Garman (1980) concluded the spread reflects the "market power" of the market maker, implying that if the market maker is not monopolistic (there are several specialists who quote bid and ask prices), the spread should fall to zero.

Stoll [1978] gives another explanation. He assumes the existence of a market maker with exogenous and unchanging beliefs about the true value of the stock. Furthermore, the market maker is assumed to be risk-averse meaning he is willing to undertake any transaction as long as his position in utility terms remains at least as good as it would be if he did not trade. Therefore, if he has to alter his portfolio away of his desired composition, he demands compensation for bearing such a risk. This compensation is the size of the bid-ask spread reflecting the costs the market maker faces. Stoll concluded the trade size affects the size of the spread analogously, while the market maker's inventory affects the placement of it.

Ho worked with Stoll [1981] to extend the intuition of the above model to a multi-period framework. Again, there is a monopolistic specialist in the market, but here, his concern is to maximize the utility of his terminal portfolio (consisting of cash and stocks). They come to the conclusion the size of bid-ask spread depends on the horizon of the market maker. In particular, they argue the spread can be decomposed into a risk-neutral spread plus an adjacent for uncertainty (a premium) increasing as the time horizon lengthens. Again, the market maker's inventory in addition to his relative risk-averse function does not affect the size of the bid-ask spread but his placement.

The Ho and Stoll model has some weak points. The assumption that the market maker accepts there is a fixed "true" price of the stock through over his time horizon seems realistic only if this time horizon is fairly short. Furthermore, a result of the model could be that traders would always be worse off dealing with a specialist who has a long time horizon as opposed to a market maker with a shorter one. This dependence does not seem to be verified in actual markets with many market makers quoting prices.

O'Hara and Oldfield [1986] relaxed the assumption of the exogenously fixed "true" price of the stock, assuming the risk-averse market maker faces uncertainty not only about the order flow he is called to meet, but also about the value of his inventory in each period. In this case, the placement and the magnitude of the bid-ask spread depend on the specialist's inventory. Thus, by allowing the spread size to change when he moves his quoting prices, the market maker gains the most flexibility to offset the changes in both the size and the value of his inventory.

Sharing another point of view, Cohen, Maier, Schwartz, and Whitcomb (CMSW) [1981] make a distinction between market and limit orders and argue that the bid-ask spread exists as a natural consequence of transaction costs charged every time an order is submitted. Further, they assume a trade mechanism without specialists with prices evolving as a result of orders crossing between traders. They argue the book of limit orders determines the size and the placement of the bid-ask spread, since the spread is essentially formed as the "hole in the book".

Two important properties are presented there: First, the spread can never collapse to zero because the certain execution of a market order induces some traders to enter market orders rather than limit orders, in addition to the fact it is not optimal (given the transaction costs) to trade continuously. Second, the spread size depends on the movement of traders between the limit and market orders, which in turn depends on the execution probability of limit orders. In thin markets, where limit execution is low, traders may prefer to submit market orders rather than limit orders. Thus, CMSW conclude that large bid-ask spreads are an equilibrium property of thinner markets.

Bagehot [1972] and later Copeland and Galai [1983] argue the bid-ask spread would even exist in a market without explicit transaction costs, due to information asymmetry. Since the market maker knows he loses whenever he trades with an informed trader, he should offset these losses by making gains when trading with the uniformed traders. These gains arise from the bid-ask spread. They argue the size of the spread differs with the elasticities of traders' demand functions, and the population parameters of the informed and uninformed traders. The most important result is that as long as there is a positive probability that some trades are informed, the spread is never zeroed.

Glosten and Milgrom, thinking on the same wavelength, suggest that trade itself may convey information. Since the market maker does not know if the trades he receives come from informed or uninformed traders, he has to protect himself by adjusting his beliefs about the value of the stock conditional on the trade that occurs. In particular, he sets bid and ask prices such that the expected profit on any trade is zero. The spread arises exactly for this reason: the fact that someone wishes to buy shares causes the market maker to revise his expectation of the asset's value upward and his quotes move accordingly, while the willingness of someone to sell causes the opposite response.

A consideration can arise here: if we assume that some informed traders possess large quantities of shares and receive some bad news, they will be in trouble since they know their trades will affect the bid-ask spread market maker quotes. They are afraid the specialist will revise his beliefs about the value of the share, which most possibly will result in a discounted liquidation of their positions. Thus, they may look for an alternative way to sell their shares. As we shall see later, liquidity options come to satisfy this need.

The third model, which tries to describe how the liquidity emerges, assumes liquidity to be *the price of immediacy*. It captures the fact that, a trader who is willing to delay transacting commands a better price than one who demands immediate execution. Grossman and Miller [1988] built a model, according to which there are two types of traders: the outside customers, and the speculators who take positions in risky assets. There is no private information: the outside customers trade only for liquidity reasons. In this model, liquidity arises because speculators absorb the excess demand of the outside customers, in exchange for the compensation given by the price change they expect to take advantage of. They end up concluding the greater the number of the speculators willing to provide immediacy, the greater the liquidity of the market.

This model, though its findings are quire interesting, is not useful for the real capital markets. The assumptions for no private information and trading only for liquidity reasons are restrictive and unrealistic with regard to stock market realizations.

Having read the above lines, one can understand, there are several different viewpoints through which, one can approach the notion of liquidity, and many variables he can use in this effort. Difficulties arise when one tries to use the models to estimate stock market liquidity. These theoretical models cannot take account of the actual trading settings and work out a clear and straight estimate. This is the reason several empirical measures have been proposed to meet this particular need.

Nevertheless, we believe the most appropriate empirical measures regarding the pricing of liquidity options are the trade size, and the first difference of the bid-ask spread, because their relation with the first and the second family of liquidity models, respectively.

In the next section, we are going to analyze the market settings of Athens Stock Exchange. It is useful to do so, in order to become aware of the price discovery process, since we will need this information later, at the pricing section.

# 3. ASE TRADING MECHANISM

In this section, we present the Athens Stock Exchange. We will become aware of its goals, the assets that are traded in, the different price formation processes, and the other settings governing its operation. We will analyze the block trading procedure and the recently adopted measures intending to provide liquidity to the market.

## 3.1 ASE AT A GLANCE

The Athens Stock Exchange (ASE) is the only official market for shares and rights trading in Greece, both for the public and institutional investors. It provides the regulatory framework for conducting transactions and for the dissemination of information from the listed companies to the investment public. The ASE also offers the issuer companies the possibility to raise capital and satisfy the demand of the investors for securities. It also enables investors to liquidate the securities they own and have a reference for the current value of their investment.

### 3.1.1 The Goals

The establishment of the Athens Stock Exchange and the issue of the first Stock Exchange Law based on the French Commercial Code were made in 1876. The Stock Exchange began to operate as a self-regulated public institution. The first securities traded on that new market were Bonds of the Greek State and shares of National Bank of Greece.The first Board of Directors was elected four years later, and since then the Athens Stock Exchange operates officially.

### 3.1.2 Historical Review-Important Dates

In 1988, the legal framework for the establishment of the Parallel market and the Central Securities Depository was provided. In 1995, Thessaloniki Stock Exchange Centre was established, having had as intention the organizing of stock market transactions in Northern Greece. Some years later, in 1997 the legal framework for the establishment of the Athens Derivatives Exchange (ADEX) and the Athens Derivatives Clearing House (ADECH) was introduced. The same law created the

Parallel market for emerging markets (EAGAK) and the market for fixed income securities. The regulatory framework for the New Market (NEHA), where small- and medium-sized companies fast growing or innovative are admitted to listing, was provided two years later, in 1999.

On 1st June 2001, Morgan Stanley included Greek Stock Exchange to its developed market index and since then a period promising financial stability and prosperity for ASE has begun.

Athens Stock Exchange performs three important functions: shares trading, block trading and bonds trading. We are going to discuss the first two operations in detail, because of their relation with our subject of study. Bond trading is not going to concern us, as it refers merely to Government Bonds in GRD, Greek Treasury Bills, Zero Coupon Bonds, and State Owned Banks' Short Term Bonds, assets unrelated to liquidity options.

## 3.2 TRADING SETTINGS

### 3.2.1 Shares Trading

*3.2.1.1 The players*

Any trading mechanism can be viewed as a type of trading game, in which players meet (not necessarily physically) at some venue and act according some rules. In the Greek stock market we meet the customers, the investors who submit orders to buy or sell shares. Brokers or brokerage firms transmit the orders from the customers to the Automated Exchange Trading System (ΟΑΣΗΣ) an electronic system through which trades are conducted. In other words, brokers act as conduits for customer orders. Brokerage firms should have obtained approval from the Board of Directors of the ASE in order to be allowed to trade.

They are classified into three categories:

a) firms with a share capital exceeding GRD 200 million/€ 0.59 mil.can only act on their clients' account and their activities are limited to floor transactions.

b) firms with a share capital exceeding GRD 300 million/€ 0.88 mil.can participate in over-the-counter transactions as dealers, both for their own account and for their clients' account. However, it should be noted that for the time being there are no over-the-counter transactions in Greece.

c) firms with a share capital exceeding GRD 1 billion /€ 2.93 mil.are allowed to do all of the above and also to underwrite new share issues.

Nowadays in Athens Stock Exchange trade 90 members-brokerage firms.

In the Athens Stock Exchange, there is no market maker or specialist, as one would expect. The market maker has the obligation to quote prices to buy (bid price) or sell (ask price) shares of every company listed in the stock exchange. In ASE there is not such a specialist, prices and consequently trades emerge in a different way. In fact, ASE could be characterized as an order-driven market. Madhavan, [1992] was the first to distinguish the market-clearing mechanisms to order-driven and quote-driven ones. According him, in a quote driven market, the market maker determines his buy and sell quotes and then orders are submitted, while in an order-driven market, the opposite happens: orders are submitted first, and trading prices are determined afterwards. In Greek capital market, since there isn't a specialist, orders are submitted first, while the settlement price of transactions arises through the matching of these orders in a continuous auction setting.

### *3.2.1.2 Types of orders handled by the system*

In the Greek stock market, we meet the following types of orders:

⇒ *At the Open Order(Εντολή στο Άνοιγμα)*: Such an order is submitted during the pre-open period. It is essentially a market order that has to be fully covered at the opening (at 10:00a.m.) with the opening price, or else, it is partially executed and the remaining part is cancelled by the system.

⇒ *Market Orders(Ελεύθερες Εντολές)* : These are orders to buy or sell one round lot of stock in the prevailing price. If such an order cannot be fully covered due to an imbalance between bidsize and asksize, it is partially executed and the remaining part becomes limit order.

⇒ *Limit Orders(Οριακές Εντολές)* : The prices of such orders are outside the range of the current quote and await the favorable movement of prices to become alive. They can be partially executed with the non-executed part of the order queuing into the system for execution at the price limit. The investors may set the period within which, limit orders have to be executed:

-good for today

-good till cancelled

-good till date

-good till executed

If a limit order is eventually executed, it allows the trader to receive a better price than the one he would have received in case he had submitted a market order. Since execution is not guaranteed (prices can always move the wrong way), one way to view limit orders is that they guarantee a price but not a quantity, while market orders guarantee a quantity but not a price.

⇒ *Stop Orders(Εντολές τύπου Στοπ)*: These orders remain inactive until their activating criterion is satisfied. Stop orders are usually referred to sell orders becoming active when a trade is made in a price equal or lower than the defined stop price. Stop orders are distinguished in:

-Stop limit orders

-Stop market orders

-On stop symbol orders: (the activating criterion of these orders does not refer to the spot price of the stock bought or sold in case of execution, but to another stock or index price)

In practice, the utility of such orders arises when the prices are falling, because they provide a bottom limit, a floor in an investor's position. Therefore, stop sell orders are also called stop loss orders.

⇒ *Immediate-or-Cancel(Άμεση ή Ακύρωση)* : Such an order has to be executed immediately, or, in the case there is no opposite order in the same price, it is cancelled.

⇒ *Fill-or-Kill(Εκπλήρωση ή Ακύρωση)* : Such an order has to be executed on whole (for all the shares), or else, if it cannot be satisfied by the opposite side's supply (/ demand), it has to be cancelled.

*3.2.1.3 Morning call auction*

In Athens Stock Exchange two different price discovery procedures take place every trading day: the morning call auction which last 15 minutes, from 9:45 to 10:00 a.m. and the main trading session from 10:00a.m. to 14:30p.m.

During the morning call auction ASE members, by order and for account of their customers submit limit, market, and at the open orders, which enter the system receiving a time stamp. The limit orders are those which determine the day's opening price. Market orders get time priority and are executed upon the opening of the market. In the case no limit orders exist, the previous closing price is set as the opening price.

For *every* prospective opening price, the sum of the shares supplied for selling in price lower than or equal to that prospective opening price, as well as the sum of the shares demanded for purchasing in price greater than or equal to the prospective opening price is estimated. The criterion used for the determination of the opening price is the maximization of transaction volume. In case two prices produce the same maximum volume, the price closest to the previous closing price is chosen.

At the first second of the main trading session, all the orders which are to be executed at the opening bid and ask prices, are executed, while the non-executed ones sustain their time stamp and enter into the central book of pending round lot orders, kept on a record by ΟΑΣΗΣ. In this way, we pass in the next price discovery method, the continuous matching of orders.

*3.2.1.4 Main trading session-continuous auction*

During the main trading session, orders are matched by price and time. In particular, orders are submitted to the system by the ASE members, distinguished to buy and sell, market and limit orders, and ranked by price and time priority. Market orders are executed immediately, while the limit orders form the central book of pending round lot orders. The criterion for the matching is the following: the sell order should have price lower than, or equal to the highest price of the existing buy orders in order to be executed, while the buy order should have price higher than, or equal to the lowest price of the existing sell orders, to be executed. As a saying " the buy order at the highest price is matched with the sell order at the lowest price". Members can change their orders, if they feel the orders cannot be executed at the given price.

Furthermore, the trading system forms a secondary book of pending odd lot orders.

The location and the magnitude of the bid-ask spread are determined by the central book of pending round lot orders. In fact the bid-ask spread emerges as "the hole in the book", where the limit orders are kept on record.

The closing price of a stock is announced officially by ASE at the end of every trading day. It is formulated as the weighted average price of the last 10 minutes of trading. If no transactions exist during this period, then the closing price is the weighted average of the last 20 minutes of trading. If no transactions exist during the last 20 minutes of the trading period, the closing price is formed as the weighted average of the day 's transactions. In case there are no transactions of a share during a day, as closing price is considered the opening price of that day.

*3.2.1.5 Tick sizes*

Since 1st January 2001, the transactions in the Athens Stock Exchange have been made in the official currency of European Union, Euro. This change effected the tick sizes, too.

Tick size is the minimum change in the stock price allowed when the number of shares offered for sale or purchase in a particular time, is totally absorbed by the investors. This potential is provided, since one of the main concerns of ASE is to ensure the continuation of the transactions. Thus, the spot price moves a little, meets limit orders waiting for execution at that price and trade continues.

Tick sizes have been set at € 0.01 for stock closing prices between € 0 –3.00, (until the end of 2000, it was GRD1 for stock closing prices between GRD 0- 999), € 0.02 for prices between € 3.00 –60.00 (the previous tick size was GRD5 for prices between GRD1.000-19.999) and € 0.05 for prices equal to or higher than € 60.00 (the previous tick size was GRD10 for prices equal to or higher than GRD20.000).

For example, let us assume that the spot price of company A is €3.75 and there are 50 shares offered for sale at this price, on the floor of the exchange. If the market buy order, which is in line for execution according its time stamp, demands 100 shares of company A, it will be executed at two different prices. This means that 50 shares will be bought at €3.75 while the rest of them will be bought at €3.77, as long as there are 50 shares available for sale at that price.

*3.2.1.6 Daily price fluctuations*

In an effort of further modernization and flexibility of the ASE framework, and under the light of the inclusion of the Greek Stock Exchange into the Morgan Stanley developed market index, the daily price fluctuations (ceiling/floor) of the shares of all the listed companies changed to plus/minus 18% from 12%, in June 1st 2001.

The daily price fluctuation limits had been imposed, in first place, to restrict the behavior of the trading mechanism in periods of great market movements in order to protect the investors. Now that ASE has been included in the developed markets, the established liquidity of the market in combination with the mature behavior of the investors guarantee for fair values for the listed companies' shares. Thus, stock exchange authorities put gradually these limitations aside, and let the market alone to determine its equilibrium prices.

Price limits do not apply in the first three days of a company's listing. Lastly, we should notice the expansion from 12% to 18% in daily price fluctuation, can only take place when the spot price of the stock remains in the previous limit (±12%) for 15 successive minutes.

3.2.2 Block Trading

Block trading is the alternative way of trading provided by Athens Stock Exchange, where large transactions- that cannot be executed on the floor of the stock exchange, due to insufficiency of bid or asksize- are executed.

In fact, block trading is a quite simple procedure. A shareholder intending to sell a large amount of a company's stock, informs his broker, and together they search for a buyer. When the buyer is found, they notify the Athens Stock Exchange for their intention by making a written application. ASE authorized personnel examines if several prerequisites are followed, and then approves the execution of the transaction. The necessary conditions are presented below.

For an order to be executed via block trading, a block value greater than, or equal to GRD 200 million /€ 0.60 mil. is needed, or an amount of at least 5% of the company 's share capital. There should be no opposite bids or offers within ΟΑΣΗΣ in values equal to or greater than that of the respective transaction. For trades exceeding GRD 400 million /€ 1.17 mil. a permission by the President of ASE is required.

For total block value amounting from GRD 200 to 400 million/€ 0.60-1.17 mil., the transaction price cannot diverge of the spot price f the stock, as it is formed on the floor of the stock exchange the moment the counterparts' application is introduced in the ASE A 5% price difference, in either direction from the current market price is permitted when block amounts to GRD 400-800 million /€ 1.17-2.35 mil., while for trades over GRD 800 million /€ 2.35 mil. the allowed price fluctuation broadens to 10% .

Finally, for the transaction to be made, the one counterpart shoule be *one* person or a firm, while for the other, a maximum of three people or firms is required.

The prices of block trades are not taken into account when estimating high, low, and closing prices of the trading day. Nevertheless, announcements of block trades are transmitted electronically during the trading session and published in a separate section of the Daily Official List.

The most significant characteristic of the block trades -which is going to concern us later, in the pricing section- is that the application form does not mention if the block transaction is buyer- or seller-initiated.

### 3.2.3 Measures Intending to Provide Liquidity to the Market

#### *3.2.3.1 Repurchase agreements*

Repurchase agreements of the same date are allowed by the ASE Board of Directors, only when one of the participating parties is a credit institution, insurance company, mutual fund or investment company and the total value of the transaction exceeds GRD 200 million / € 0.60 mil. They are conducted in the same way as block trades.

*3.2.3.2 Margin Account*

With the term margin account, we mean the investor's ability to buy shares on the floor of the stock exchange on credit. The measures of margin account, stock repo, stock reverse repo and short selling came into force on the eve of the upgrading of the Greek Capital market on 1st June 2001.

In order an investor to be able to buy shares on credit, he must deposit funds in what is called margin account. The amount deposited when the investor enters in such a position is known as initial margin and usually composed by the shares he buys by this procedure. Cash, company shares traded in ASE, Greek Treasury bills and Eurozone Government Bonds are also accepted.

The initial margin gives the ability to the investor, to buy shares up to the double of the initial margin value. For example, assume an investor buying on credit 100 shares costing €50 each. He has to deposit to his broker (ASE member) €2.500 as initial margin, while for the rest he takes credit. Every trading day the shares bought are marked to market and if the balance in the margin account is above the initial margin, the investor can buy shares up to the double of this surplus. Thus, if the next day the spot price of the shares bought on credit increases, let's say 60€/share, then there is margin surplus €500 (50%x6.000 –2.500). In this case the investor can buy shares with value €1.000 without paying any cash, while his initial margin will be formed at €3.000.

There also exists the maintenance margin (which is 35% of value of the purchased shares). If the balance in the margin account falls below the maintenance margin then the investor is called to cover the margin deficit in three trading days, or else the broker sells the part of investor's position needed to cover the deficit.

In the case the investor wishes to close his position by selling his shares, the broker deducts the amount of credit given previously from the investor and gives him the rest of the payoff.

### *3.2.3.3 Stock lending - Stock borrowing*

The stock lending and the stock borrowing products are trading through the Athens Derivatives Exchange (ADEX), in the form of Stock Repo and Stock Reverse Repo contracts. The main purposes of these products are:

i. The creation of a pool of lenders for each stock,

ii. The provision of the potential to the investors to borrow stocks from pool in order to meet their delivery obligations arising either due to short selling or from derivative products requiring delivery.

In stock Repos, the seller delivers his stocks to Athens Derivatives Exchange Clearing House (ADECH), and receives, in exchange, income, which ADECH collects by lending the shares further. This income is not known or guaranteed in advance. The size of the contract equals to 100 or 1000 shares, depending on the stock price. At any point of time, only one stock Repo series is available for trading, the maturity of which is the last working day of each calendar year.

The procedure is the following: Every trading morning, ADECH introduces in the trading system a buy order for a specified quantity (expressed in contracts), per stock, at a specific bid price. This price is derived from the total undistributed income over the number of the shares that has been sold via the reverse Repo series and describes the undistributed income per lent stock plus 100 eurocents. Investors place market sell orders for the quantity of contracts they are willing to lend. The orders are executed using strict time criteria until the total quantity required by ADECH is fulfilled. Depending on the demand, ADECH has the right to increase or decrease the quantity of shares it planned to absorb, without changing the daily price.

Once a month, ADECH reimburses the sellers with the accumulated income as follows:

i. For trades that took place during that month:

(end of month price – trading day price) x (number of contracts) x (contract size)

ii. For trades that took place before the last day on which ADECH distributed income:

(end of month price –100) x (number of contracts) x (contract size)

The seller (lender) may request back the total or part of the contracts sold during any day (up to the expiration day of the series). The securities are returned to the seller on the fifth trading day from the exercise day, while the related income is distributed the following day after the exercise day.

As concerns the stock reverse Repos, borrowers are the investors, while the only lender is ADECH. Again the contract size is equal to 100 or 1000 shares, while the maturity of the contract is 6 months from the trading day. In fact, it is the product that gives the investors the ability to use stocks from the ADECH "pool" to cover their short selling positions.

The procedure followed is similar to the one just described for stock Repos. Every morning, ADECH inserts a sell order for a specific quantity of stocks on specific ask price (expressed as interest rates) and then investors submit their market buy orders. Thus, in contrary to ASE, the trading mechanism here is quote driven, since the ADECH quotes the bid-ask prices and afterwards the investors choose their positions.

Each day that the buyer holds the stock reverse Repo, he has to pay in advance the daily interest, which is calculated as:

(fixing price on trading day) x (number of contracts) x (contract size) x (number of days)x (trading price/36.000)

where the fixing price for the trading day is the official closing price of the stock on the previous trading day, while the number of days are the calendar days between the two consecutive trading days following the day the interest is calculated.

The buyer (borrower) can return the total or a part of the contracts he borrowed during any day in the six-month period, while the physical delivery of the stocks will take place four working days later.

For the time being the stock Repos and stock reverse Repos are applied in 75 listing companies in ASE, most of which comprise the FTSE 20 and FTSE Mid 40 indexes.

*3.2.3.4 Short Selling*

Short selling is the procedure through which an investor sells in the market shares that does not own and has been borrowed. This strategy is mainly used by the investors when they believe the price of the stock is going to decline shortly.They short the stock today in order to buy it back, in the near future, in a lower price. As soon as the investor buys it back, he has to give it back to the lender -in Greek Capital market, the ADECH- from whom he had borrowed the stock in first place. The investor's payoff is the change to the price of the stock, which will be positive if investor's expectations are realized, otherwise negative, when prices move to the opposite direction.

A short sale, in order to be executed has to be in trading price higher than the previous one (uptick rule) and should be flagged as short in order to be cleared by ADECH.

# 4. NOTION OF LIQUIDITY OPTIONS

In this section, we first discuss the notion of options in general, and then focus on liquidity options. We analyze their features and present a formula for their pricing.

## 4.1 INTRODUCTION TO OPTIONS

In this part, we give the definition of options and the related payoffs, while later in the section of valuation, we will discuss the option pricing process, introduced by Black, Scholes, and Merton.

*An option* is an example of a derivative security. *A derivative* is a financial instrument whose value depends on the values of other more basic underlying variables. The underlying assets of options include stocks, stock indices, foreign currencies, debt instruments, commodities, and futures contracts. In this paper, we are going to concentrate our discussion on stock options.

An option gives the holder the right to do something. In particular, a *call option* gives the owner the right to buy the underlying asset, at a specified *exercise* or *strike price* (X), on or before a specified *expiration date* or *maturity*. Similarly, a *put option* gives the holder the right to sell the underlying asset at a specified *exercise* or *strike price* (X), on or before a specified *expiration date* or *maturity*. The option that is to be exercised only on one particular date, is called *European*, while the one that can be exercised on or at any time before the expiration date is known as *American*.

We have to emphasize the fact that an option gives the holder the right, but not the obligation to do something. This is the great advantage of options over the futures and forwards, where the holder is committed to buy or sell the underlying asset, no matter how the price of the underlying asset has turned out to be on the maturity date. This is the reason why, it costs nothing to enter on a forward or futures position, whereas there is a cost to acquiring an option position (the *price* or the *premium* of the option).

Let us make an example: Suppose that the company A writes European call options (goes short call) with exercise price X on its stock with maturity one year. An investor buys one (goes long call) and pays a p amount of money, the price of the option. By this contract, the writer undertakes the obligation to give up 100 shares if at the maturity, the holder asks him so. Let us assume that at the end of the year (at the expiration date), the share price is below the exercise price $S_T < X$, then the call option expires worthless, as the investor has no reason to exercise it and the seller's liability is zero.

In the opposite case, where the spot price of the stock turns out to be higher of the exercise price $S_T > X$ at maturity, the buyer exercises its right, while the seller (the company) has the obligation to give up the shares for the specified exercise price. Thus, the buyer earns the difference between the spot price of the stock and the exercise price, while the seller loses it. So in the investor's shoes, the payoff of a long position in a European call option at maturity is

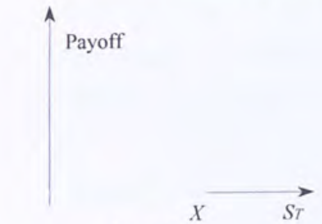
$$\max(S_T - X, 0)$$

On the other hand, in the company's shoes, the payoff of a short position in a European call option at maturity is

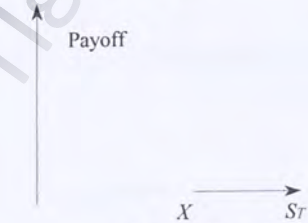
$$-\max(S_T - X, 0) \quad \text{or}$$

$$\min(X - S_T, 0)$$

Using diagrams, the arguments are understood more easily:

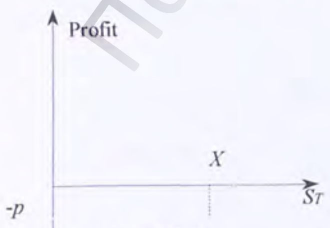



Long Call

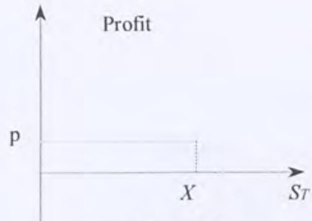



Short Call

Taking into account the amount of money paid by the investor, for entering in an option contract (the price of the option), and assuming the time value of money does not play any role here, the profits for the buyer and the seller, at the expiration date, are formed as following:




Long Call




Short Call

Moving further to the put options, let us assume our investor buys a European put option (goes long the put) with maturity one year and exercise price X. In other words, he buys the right to sell 100 shares at price X at the end of the year, irrespectively of the spot price of the stock at that particular time. Thus, at the end of the year, if the spot price of the share turns out to be higher than the exercise price ($S_T$ >X), the option expires worthless because the holder of the option has no reason to exercise it, since he can sell the share at the market in a better price.

In the opposite case, where the spot price is below the exercise price at the expiration date ($S_T$ >X), the holder exercises the option, sells the shares to the writer, who has the obligation to accept the shares if the holder decides so.

The related payoff for the holder of a long position in a European put option is:

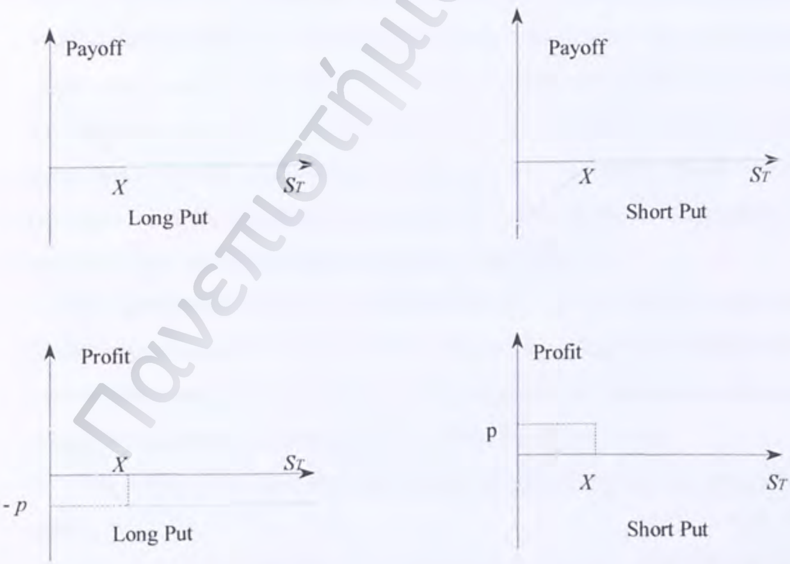
$$\max(X - S_T, 0)$$

and the payoff from a short position in a European put option is:

$$-\max(X - S_T, 0) \quad \text{or}$$

$$\min(S_T - X, 0)$$

The figures below illustrate the payoffs and the associated profits, if we take into account the initial outflows:




Later, we will discuss thoroughly the methodology used in order to end up at a price for the option, for the moment, we are going to deal with the peculiar notion of liquidity options.

## 4.2 INTRODUCTION TO LIQUIDITY OPTIONS

*Liquidity option* is a put option a company writes on its stock. It is addressed to its large shareholders. The notion of liquidity option is somewhat known to all the interested parties, but the complexity of its pricing, prevent it from being used. Nevertheless, due to this complexity, Liquidity options are interesting and challenging. They have the following peculiar characteristics:

***i. Liquidity option is an embedded option in company's stock.***

Each investor who buys shares of company A, takes with the purchased shares a valuable intangible asset: the ability to sell the shares back to the company, whenever he wishes within a predetermined time interval (let's say one year). This right is very significant, the explanation follows.

Imagine an institutional shareholder wishing to rebalance his portfolio for some reason and decides to sell the shares of company A he possesses. He has two alternative solutions, he can sell them either "on the floor of the stock exchange"(he submits an order in the Automated Exchange Trading System), or via *block trading*.

If he decides to sell them on the floor of the exchange, he may have to wait days in order to sell all the shares. He should split the total amount of shares to be sold in small orders in order to be hidden behind the usual daily stock volume variance and avoid sudden price movements. A market order submission for the total amount would cause the spot price to decline sharply or to "lock" in the bottom daily limit for some time( if such variance limits exist). On the other hand, block trading will, also, take him some time possibly days in order to be achieved. Meanwhile, our investor may have lost some significant investment opportunities.

No matter what our large shareholder decides, the liquidation of the shares will not be immediate not to mention it may result in a huge price depression. Liquidity options therefore provide the share with a significant comparative advantage over the others: the guarantee of immediate liquidation to the investors.

***ii. The strike price of a liquidity option is not settled at the time the contract is made.***

The buyer of a liquidity option is the one, who decides when and in which price he is going to exercise the option, if he decides so. In other words, the holder of a liquidity option has the right to give the shares he possesses, back to the issuer of the option whenever he wishes so, while the company undertakes the obligation to repurchase its shares and compensate the investor with the spot price of the stock, as it is formed that particular moment on the floor of the stock exchange. Thus, the exercise price always equals the current price of the stock (X = S).

***iii. From one perspective, a liquidity option is a summation of exotic options, namely a summation of forward start put options.***

A *forward start option* is an option that starts at some time in the future(see Hull, *Options, Futures and Other Derivatives*, p.460, chapter 18).

There are two viewpoints for pricing a liquidity option. The first argues a liquidity option is composed of a series of European forward start put options, each of which has as time to maturity one day. At the beginning of day t an option is born, and dies at the end of the same day, another follows the next day, the day after and so on. Alternatively, liquidity option can be viewed as an American put option -in the sense it is exercised whenever the buyer wishes until some day in the future, but with its strike price changing every day.

We will focus our discussion on the first perspective, the second refers to American options in which Black-Scholes formula cannot be used for pricing. Moreover, the strike price of the American option changes every day, complicating further the pricing of the option.

***iv. In the first place, the value of each of the forward start put options seems to be zero.***

Modifying the payoff for the holder of a European put option to take account of the strike price that is equal to spot ( X = S ), we conclude that:

$$\text{Payoff of a long position of European put option at maturity} = \max(X - S_T, 0) = \max(S_T - S_T, 0) = 0$$

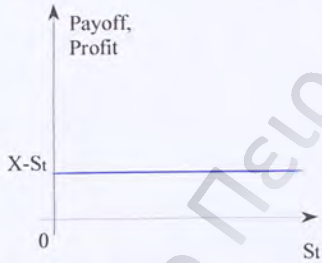
there is no reason why somebody to prefer to exercise the option instead of shorting the stock to the open market. This consideration is rational when the trade size is small, while for institutional shareholders or investors possessing large quantities of shares things change. Their decision to sell a large amount of their shares on the floor of the stock exchange (larger than the asksize) is going to have a serious price impact. How large this depression will be, is what we will try to estimate. This price impact is called *liquidity effect* and refers to the percentage of the initial spot price that the investor has to sacrifice, in order to liquidate immediately his position.

Having in mind all the above, we conclude that the payoff of a long position in a European forward starting option with time to maturity one day and S=X is equal to the liquidity effect that an investor has to suffer when he does not own such an option.

*v.* ***Shareholders do not pay any premium for obtaining such an option.***

We have already said that the liquidity option is an embedded option in the company's stock. It is an offer from the company to its shareholders, thus the investors does not bear its premium, they are not even aware of it.

Since there is not any initial outflow for the investor, the payoff and the profit of a long position in a liquidity option are exactly the same at any time within the life of the option. Diagrammatically this argument can be viewed as following:




Putting the premium equal to zero does not mean that the liquidity option does not cost anything. It does have a cost, but it comes in company's charge. This cost we are called on to estimate.

As soon as we take an estimate for the S/X ratio, we use it in the Black –Shcoles formula and take a price for the forward starting European put option. The argument stating the plain vanilla European put options are less valuable as the stock price increases and vice versa doesn't apply here. In fact the price of such a forward start put option is independent of the spot price of the stock, while it is highly dependent on the S/X ratio of it. We will discuss this issue later.

We assume that the estimation for the S/X ratio remains valid and constant for the next year ( or 252 trading days ), consequently each forward start put option has the same price p. Since the liquidity option is a sequence of forward start options, its price can be expressed as the sum of the discounted present values of the forward start put options, that is:

$$\ell = \sum_{t=1/252}^{1} pe^{-rt}$$

where

$\ell$ = the price of the liquidity option with time to maturity one year

$p$ = the price of a forward starting put option with life of one day

$r$ = the risk free rate continuously compounded plus 20 b.p.

$t$ = time in years, at which a forward starting put option begins

The reason why we discount the money flows with the risk free rate plus a risk premium of 20 basis points, is that we have to take into account the default risk an investor runs when he decides to exercise the option and the company may deny to repurchase its stock. This possibility is quite small but it does exist, resulting in the imposition of the risk premium.

An important disadvantage of the liquidity options is that the issuer of the option cannot be certain for the exact timing of the cash outflows, it will have to face in the future. Additionally, it can end up being excessively borrowed (when many investors decide to execute their liquidity options at the same time and thus it has to be borrowed in order to pay its obligations.). In that case, stockholders would press for a higher rate of return to compensate for the greater risk of default they undertake. The weighed average cost of capital would rise, consequently the value of the firm would decrease.

As a conclusion we could say, a company should consider very carefully the drawbacks and the benefits (the utility) of such an option. In the next section, we discuss the utility liquidity options provide to the involved counterparts.

# 5. USE OF LIQUIDITY OPTIONS

In this section, we present the reasons why the interested counterparts (the listed companies and the large investors) would like to use a liquidity option. We also present the obstacles the legal framework puts to the issuance of such an option.

## 5.1 WHY WOULD A COMPANY LIKE TO ISSUE SUCH AN OPTION?

A product has a reason for existence, if, and as long it provides utility to all the involved parties. Having this in mind, we should search for reasons, which would make a company willing to write a liquidity option on its stock, and a large stockholder willing to obtain it.

The question naturally arising is why a company would like to repurchase part of its stock. (An inherent assumption is that the company's shares are traded in an organized stock exchange) There are some reasons for such a choice, presented below:

⇒ ***In the last years, more and more companies repurchase part of their stock in order to provide them to their personnel.***

It has been observed that employees become more devoted to their job, after they have obtained some shares of the company they work. As far as the blue-collar workers are concerned, the stock offering may be a reward for their hard efforts to obtain some quantitative targets. In the same time, it is considered an incentive for the workers to keep working with the same pace in order to obtain more shares in the future.

Alternatively, the company may sell a stock option to its employees. Usually, employees pay a premium to buy this option. In some cases, stock options are given for free. By obtaining such an option, employees have the right, after some time, to buy company's shares from the firm in a predetermined discount.

When it comes to top executives, the usual case is the company agrees to deliver an amount of its repurchased shares to the top management, provided that some specified targets will be met.(e.g. a target of a 25% rise of the company's EBIT for the next year).

⇒ ***The company may desire to change its capital structure.***

Despite the first proposition of Modigliani – Miller arguing that "the value of any firm is independent of its capital structure", today firms watch closely their capital structure. We have to notice here, that MM propositions have been built upon the crucial assumption of perfect capital markets, which does not hold in the real world. So, there must be some place for the debt policy.

By adopting either the "Traditional Position" theory or the "Trade-off theory of capital structure," the company can come up to an optimal Debt/Equity ratio. Traditionalists argue that when a firm has a minor Debt/Equity ratio, the weighted average cost of capital declines, at the beginning. Later as the company starts to be excessively borrowed, the weighted average cost of capital increases significantly. Thus, somewhere in the middle, there should be an optimal debt/equity ratio, which minimizes the WACC.

On the other hand, the "Trade-off theory of capital structure" argues that the value of one levered company can be expressed as follows:

Value of the firm = value of the firm if it was all equity financed + PV(tax shields) – PV(costs of financial distress)

At moderate debt levels the probability of financial distress is trivial, so the PV(cost of financial distress) is small and tax advantages dominate. But at some later point, the probability of financial distress increases rapidly with additional borrowing, and overpasses the tax advantage of the debt. The "trade-off theory of capital structure" argues the firm's value reaches its optimum when the present value of the tax savings due to additional borrowing is just being offset by increases in the present value of cost of distress.

In case the firm is discovered to have more equity than it should have had, it has two alternatives: it can either borrow further, (i.e. by writing a bond), or it can repurchase and cancel the necessary part of its stock in order to achieve to optimal Debt /Equity ratio.

⇒ ***The company may suffer significant losses and desires to write-off the loss amount by reducing its equity capital.***

In that case, the company repurchases an amount of stocks with book value equal to the loss amount. Next, these shares are cancelled, and in its books the loss is depreciated. Of course, this equity capital reduction is not going to be interpreted as good news for the firm, but it is not of our concern for the time being.

⇒ ***In the case the spot price of the stock follows a downward trend for a relatively large period of time.***

If the company considers the spot price of the stock to be significantly lower than that corresponding to its financial status and prospects, it has the right to intervene and support its stock by buying an amount of its shares. This movement, in most cases, is considered as good news for the firm.

Beyond that, in cases where the spot price of the stock follows a downward trend for a long time, the risk of a hostile takeover arises. As the firm depreciates further and further every day in the stock market, some investors' trust in the company's promising prospects may be shaken, and a proposal of exchanging their shares for a relatively generous cash amount per share may seem interesting to them.

Alternatively, the relatively low spot price of a listed firm may seem very attractive to an investor who may start collecting the company's shares supplied in the stock market, in order to aggregate the majority of them. Assuming he succeeds, he invites the shareholders of the firm in general meeting, brings down the management and elects his own one.

By deciding to repurchase part of the firm's stock in time, the management reduces the number of shares on free float, controls a higher percentage of the company's stock, and by this way carries off the risk of a hostile takeover.

All the above reasons explain why a decision for a "share buy-back policy" can prove to be meaningful and beneficial for the company.

Nevertheless, a question arises: why would a company use a liquidity option to repurchase its stock instead of going to the open market and obtaining the shares there?

We have indirectly referred to this subject earlier and already given the answer. As we have said, a liquidity option is an embedded option in the firm's stock, which means that it is a free offer from the company to its large shareholders. This right gives a comparative advantage to the company' stock over the shares of the other companies that trade in the same sector. In other words, this offering is expected to be appreciated by the market, since the promising prospects of the firm will be reinforced further, consequently, a positive impact in the company's spot share price is awaited.

Furthermore, liquidity options can be seen as a measure of protection of the spot price of the stock against sudden falls that may happen due to a large shareholder's decision to sell its shares in the open market.

Last but not least, we should notice that a share repurchase on the secondary market is liable to a very strict legal framework demanding a binding procedure to be followed by the firm.

In the next section, we explain the reasons why a shareholder would like to sell a company's shares, and then we are going to examine the Greek legal framework touching the share repurchase.

## 5.2 WHY WOULD A LARGE SHAREHOLDER LIKE TO EXERCISE A LIQUIDITY OPTION?

We have already stated the reasons for which a firm would be willing to repurchase part of its stock, and why it is more preferable to do this through an issuance of a liquidity option.

We now turn to the other side of the transaction: the large shareholders. We have already assumed that the shares of company A are being traded in a stock exchange (e.g. Athens Stock Exchange), and we assume further, that some institutional traders hold large amounts of company's A shares.

Some possible reasons which would make the large shareholder to sell company's A shares are presented below:

⇒ ***Rebalancing of his portfolio***

In regular time intervals, institutional shareholders rebalance their portfolios aiming at maximizing the expected return and minimizing the systematic risk of their positions. In this effort they estimate the expected return of their portfolio E(Rp) based on historical data, the beta coefficient expressing the systematic risk of the portfolio, the correlation coefficient ρ of the returns of the shares composing the portfolio, as well as the $R^2$ coefficient.

By estimating the above parameters, the portfolio managers decide if and how many shares have to be sold. For example, when there is a downward trend in the market, mutual funds most possibly decide to become more " defensive" in order to minimize their losses, by adopting a beta coefficient less than one. Thus, they will sell companies' shares with beta coefficients higher than one ($\beta > 1$) and replace them with shares of other firms with lower beta and a relatively high $R^2$ coefficient - meaning the returns of these shares watch closely the defensive behavior assumed by their low beta coefficients.

⇒ ***Inside Information***

A large shareholder may have some information he believes will have a negative impact on the spot price of the firm's stock (i.e. he gets informed there is a serious decline in the firm's EBIT). In this case, he may try to sell the shares of the company he possesses before the market becomes informed, in order to avoid a significant haircut on his position.

Alternatively, the shareholder may have good information for a company, and wishes to speculate on its stock, as he finds the price of the stock quite attractive and its expected return quite promising. If he does not have a savings account, he may sell the shares of another firm in order to take advantage of this investment opportunity.

⇒ ***Orientation of the fund***

This argument refers to international institutional funds investing in many markets all over the world. These funds usually refer to indexes formed by institutional houses for the allocation of their investments.

Thus, let us consider an international Fund orientated in Emerging markets that had invested in the ASE before the inclusion of the Greek stock market in the Morgan Stanley developed market index. Due to this upgrading, the Emerging markets' fund closed its position and left the Athens Stock Exchange, while other funds investing in developed stock markets entered Athens Stock Exchange.

All the above arguments are reasons for a shareholder to sell the shares he possesses. Nevertheless, the selling of these shares by executing a liquidity option satisfies a very significant need of the investor that cannot be satisfied by any other mean: the need for immediate liquidation of his position.

In particular, as we have already discussed, there exist two alternatives: He can either sell the shares in the open market, or he can go via block trading. By the first procedure, he should submit small limit orders for several days, in order to be hidden behind the usual daily stock volume variation. This procedure is going to take some days to be completed, so it does not serve the investor who needs cash immediately.

Someone might wonder why the shareholder does not submit a *market* sell order, so as to liquidate its position immediately. With the assumption that, the size of such a sell order would overrun the asksize, such a move would dramatically reduce the spot price of the stock. In particular, the price of the stock would probably 'lock' to the daily low limit for some days maybe (if the stock exchange displays allowed daily price fluctuations, as ASE does), or else, suffer a dramatic decline until the market is able to absorb this large quantity of shares. Not to mention, that this fall of the spot price will not leave indifferent the other investors, they will try to "get rid of the stock" as soon as possible, in order to save whatever they can. So, the decline of the stock price will be exacerbated further.

Thus, selling the shares in the market is going to cost the shareholder a lot of time and money, as the market is going to ask for compensation for taking such large position.

The alternative outlet for the shareholder would be to find an investor and agree to sell his shares to him. This procedure is going to take some time, too. The counterparts should apply to ASE, authorized personnel would examine the applied transaction, and if the prerequisites are followed, the execution of the transaction will be permitted.

Thus, either by the open market, or via block trading, our investor is not going to sell the shares he owns without time delay and possibly discount. There lies the reason for existence of liquidity options. We argue there can be a third alternative for the large shareholders, with a proper law amendment. In that case, by exercising the liquidity option embedded in stocks, the investor would give the shares back to the company in the current spot price and without time delay. By this way, he would avoid a haircut on his position and satisfy the need for immediate liquidation of his position.

## 5.3 GREEK LEGAL FRAMEWORK FOR STOCK REPURCHASES

The legal framework in effect in Greece forbids a societé anonyme to possess its own shares. There are four well-defined exceptions, in which stock repurchase is permitted:

i. The repurchase of part of a company's stock by itself is permitted, when it aims at the reduction of the firm's equity capital. Such a reduction is usually down to write-off significant loss amount. For this purpose a majority decision of the General Meeting of the company 's shareholders is needed. The shares are bought and cancelled, while in the company's books the loss is depreciated.

ii. A financial institution can purchase a part of its own stock, not for itself, but by order and for account of its customer.

iii. A firm can repurchase part of its stock, up to 10% of its equity capital, in order to distribute them to their personnel within a year. Also, the law permits the offering of stock options with maturity up to 5 years to the personnel. In this case, the company is allowed to possess the shares for the above time interval.

iv. Listed companies may acquire their own shares through the A.S.E. up to a limit of 10% of the total amount of their shares outstanding, by majority decision of the General Meeting of the company's shareholders, in order to support the market price. Such a decision is acceptable in cases where the spot price of the stock is considered significantly lower than that corresponding to the financial status and company prospects.

The decision has to be published at least ten (10) days before buyback and each time it is implemented in at least 2 daily newspapers of nationwide circulation and in the ASE Daily Official List.The press release should include exact information about the maximum volume of shares to be repurchased, the maximum price in which the company wishes to buy the shares and the time interval within which the repurchase will be completed(it cannot surpass 18 months). If the shares acquired through this procedure are not sold or distributed to the staff of the company, within three years from the repurchase, they are cancelled by decision of the shareholders' General Meeting.

We observe the existing legal framework does not allow latitudes for the liquidity options to come into place. Nevertheless, as the aim of law is to serve and defend the needs of the human society, we believe that, as soon as the scientists get in agreement on their pricing and come up with an integrated proposal to the stock markets, stock exchanges will appreciate the great utility liquidity options provide, and consequently, the legal frameworks will be revised in order to include such potential.

## 6. VALUATION OF LIQUIDITY OPTIONS

In this section, we analyze the pricing methodology we are going to use, the data, and the different approaches we follow in order to estimate the liquidity. We then present the prices of the options and make an inter-temporal analysis of liquidity concerning the three shares available.

### 6.1 INTRODUCTION TO PRICING METHODOLOGY – BLACK- SCHOLES FORMULA

In previous chapter, we have already analyzed a liquidity option can be seen as composed of a series of European forward start put options, each of which has a maturity of one day, or else, as an American put option whose strike price changes every day. In this paper, we concentrate our efforts on the first perspective, we leave the second one for future scientific research.

What we have to do is to work out a price for each of these put options and then to sum them up, by discounting them with the risk free rate plus a risk premium. We have presented this procedure as

$$\ell = \sum_{t=1/252}^{1} pe^{-rt} \qquad (6.1)$$

where

$\ell$ = the price of the liquidity option with time to maturity one year

$p$ = the price of a forward starting put option with time to maturity one day

$r$ = the risk free rate plus 20 b.p.

$t$ = time in years, at which a forward start put option begins

In order to price each of the forward starting put options, we are going to use the Black- Scholes Formula.

The B-S Formula was first introduced in 1973 and since then it is the chief instrument for the pricing of plain vanilla options. There are some important assumptions made in order the B-S differential equation to be derived:

- *The return of stock price follows the Geometric Brownian motion.* The discrete-time version of Geometric Brownian motion is:

$$\frac{\Delta S}{S} = \mu\Delta t + \sigma \in \sqrt{\Delta t} \Leftrightarrow$$
$$\Delta S = \mu S\Delta t + \sigma S \in \sqrt{\Delta t} \qquad (6.2)$$

where μ is the expected return of the stock price, σ is the volatility of the stock price and ∈ is a random drawing from a standardised normal distribution, ϕ(0.1). This means the return of a stock is assumed to be normally distributed with mean the expected value of the return μΔt and standard deviation σ√Δt increasing with the square root of the time as we are looking ahead. The significant assumption, here, is that the parameters μ and σ are constant.

In particular, by μ is meant the expected continuously compounded return earned by an investor in a year. Also, as volatility σ is taken the standard deviation of the continuously compounded return provided by the stock in one year. We can estimate volatility from empirical data using the continuously compounded return:

$$u_i = \ln\left(\frac{S_i}{S_{i-1}}\right) \qquad (6.3)$$

and estimating the standard deviation of *ui* 's:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(u_i - \bar{u}\right)^2} \qquad (6.4)$$

According to the Geometric Brownian motion, the standard deviation of the continuously compounded return is σ√τ, where τ is the lengrth of time interval in years. Thus:

$$s = \sigma\sqrt{\tau} \Leftrightarrow \sigma = \frac{s}{\sqrt{\tau}} \qquad (6.5)$$

If the empirical standard deviations are taken from daily returns, we put τ=1/252 in order to take an estimation for volatility per annum.

- *The short selling of securities with full use of proceeds is permitted.*

This assumption is made necessary, because what the B-S formula, or the Binomial model tries to do by one perspective, is to replicate the possible payoffs of a put option, with a combination of shorting stock and lending a loan (and vice versa for call options).

- *There are no transaction costs or taxes. All securities are assumed to be perfectly divisible. Additionally, there are no dividends during the life of the option, while the risk free rate of interest is constant and the same for all maturities.* All these assumptions are made in order to make the pricing of the option as simple as possible.

- *Finally, it is assumed there are no riskless arbitrage opportunities, while security trading is assumed to be continuous.*

It is easily understood these assumptions are at some distance from the reality in the capital markets. Nevertheless, B-S differential equation gives us a price for the option, which can at least be used as a point of reference.

The differential equation which Black, Scholes and Merton worked out, was later modified by D.French in order to take account of the empirical researches suggesting the volatility of an exchange-traded instrument is higher when the exchange is open than when it is closed. This is the version we adopt in this paper. It is formed as following:

For the price at time zero of a European put option on a non-dividend paying stock we take:

$$p = Xe^{-r\tau_2} N(-d_2) - S_0 N(-d_1) \qquad (6.6)$$

where

$$d_1 = \frac{\ln(S_0 / X) + r\tau_2 + \sigma^2 \tau_1 / 2}{\sigma \sqrt{\tau_1}}$$

$$d_2 = \frac{\ln(S_0 / X) + r\tau_2 - \sigma^2 \tau_1 / 2}{\sigma \sqrt{\tau_1}} = d_1 - \sigma\sqrt{\tau_1}$$

*N(x)*: the cumulative probability distribution function for a variable that is normally distributed with a mean of zero and a standard deviation of 1.0

$S_0$ : the spot price of the stock at time zero

$X$ : the exercise price

$r$ : the continuously compounded risk free rate

$\sigma$ : the stock price volatility per annum

$\tau_1$ : (trading days until maturity) / (trading days per year)

$\tau_2$ : (calendar days until maturity) / (calendar days per year)

Coming back to our objective, which is to price a sequence of daily, forward starting, put options, we look closely the B-S formula. We notice that it demands an exact prediction of the spot price of the stock and the exercise price. Since there is no way to predict precisely these variables, we are going to modify it, so that it consists of variables more easily estimated. If we divide the two parts of the equation with X, we take:

$$p = Xe^{-r\tau_2}N(-d_2) - S_0 N(-d_1) \Leftrightarrow$$
$$\frac{p}{X} = e^{-r\tau_2}N(-d_2) - \frac{S_0}{X}N(-d_1) \qquad (6.7)$$

What we did essentially, was to express the price of our option as a percentage of its exercise price. The transformation created a rather peculiar ratio, $S_0/X$. As we have already said, in our case, each forward start option has its exercise price to be equal to the spot price of the option. It seems this ratio is equal to 1, which is true for relatively small orders. In the previous section, we explained thoroughly that, if a relatively large sell order enters the system, it is going to cause a significant depression on the spot price of the stock.*

The spot price of the stock in which the large sell order will be executed is the weighted average of all the prices used until the large sell order is entirely satisfied. The weights for this calculation, as one can guess, will be the number of shares sold in each spot price. The weighted price will be formed lower than the spot price in which the order would be executed if there were enough shares supplied in the market. The difference between these two prices is called liquidity effect, since it is generated by the lack of liquidity at the stock market.

Having made clear what the numerator of the ratio represents, we move further to the denominator. Denominator asks for the exercise price of the put option, which we have already defined to be the spot price of the stock. For small sell orders these two prices will not diverge, thus there is no utility for investors with small amounts of shares, of using such an option( since the payoff of the liquidity option is equal to zero). On the contrary, when it comes to large sell orders, there will be some distance between the two prices. In particular, this distance will be equal to the liquidity effect.

An example will illustrate more clearly this argument: Let us consider a stock that is currently traded on the floor of the exchange, with a price equal to €6.5. The size of the bidside on this price is 1.100 while an investor wishes to liquidate 6.000 shares. If he enters a market sell order, the price will decline sharply, thus the weighted average price of the transaction will be much lower than €6.5. On the other hand, if the investor decides to exercise the option embedded in the stock, he will sell all its

* We name an order as large when its size overpasses the number of shares offered on the floor of the stock exchange, at a particular moment and spot price

shares at the price of the stock as it is formed on the floor of the exchange. So, the exercise price of the option will be €6.5.

Since our liquidity option is intended for investors who possess a large amount of company's shares, the S/X ratio demanded for the pricing of the forward starting put options, will be less than one, by the percentage of liquidity effect. This is what we will try to estimate in the rest of the paper, namely the decrease in the spot price of the stock due to lack of liquidity in the market.

Someone could argue our investor would choose to trade in the "upstairs market" where block trading takes place, instead of selling its shares "downstairs". This would be the case if our investor were not interested for immediate liquidation of his position, since this procedure takes time in order to be completed. It would be certainly interesting to observe this procedure and reach some conclusions about the difference between the spot price of the stock, as it is formed on the floor of the stock exchange, and the price in which the particular block sale is settled.

Unfortunately this cannot provide any tangible results, due to the lack of information about the part initiating the block trade. In other words, in order to estimate the price difference between the spot price on the floor and the price of the block sale upstairs, we have to distinguish block trades in seller-initiated and buyer-initiated and to work only on the seller-initiated ones, the ones interesting us. The ASE does not provide this particular piece of information, since counterparts meet outside the exchange, arrange the transaction, and only afterwards, they notify the ASE of their intention.

Consequently, we return to our previous thought about estimating the liquidity effect from data taken from the continuous market. In this effort, we are going to use some assumptions in order to create a well-defined environment in which liquidity options will be priced. We will present these assumptions gradually during data processing, as the need arises.

## 6.2 THE DATA

The data used are intraday price, quote, and volume for three listed companies' shares. Since every stock does not behave exactly the same way to a submission of a large sell order, we are going to concentrate on ordinary shares of three listed firms: ALPHA ΤΡΑΠΕΖΑ, OTE, and ΑΕΓΕΚ. The first two participate in the FTSE 20 index, which consists of large capitalization companies, while the third one participate in the FTSE Mid 40 index, consisting of medium capitalization firms. The reason behind our choice is to watch how the different daily volumes affect the S/X ratio.

By intraday data, we mean all the data available for each transaction on the ΟΑΣΗΣ (Automated Exchange Trading System). They include volume, transaction time, bid and ask of each transaction, and their respective depth before every trade.

We collected data for August, September, and October 2000, since we want to observe how the S/X ratio was formed in these three months in which the market moves gradually from low volumes (August) to its heating (September and October, see Diagram 6.2.1)

We also checked the number of shares outstanding ("float") for these companies and found it to be constant, so no misleading effects of equity capital increases will be presented in our study. During the same time interval, there was no announcement or intense rumor (such as information about dividend distribution or a merger concerning one of the chosen firms), which could also dispute the quality of our results.

The source for data collection was the Grstocks.com. This company provides intraday data for every stock listed on ASE. Table 6.2.1 displays the data format.

We are mainly interested to observe the decrease in the spot price of the stock due to a large sell order; hence, we need to watch the price impact of a large sell order execution. First of all, we have to assume our investor, who possesses a large amount of shares wishes to liquidate his position by submitting <u>one</u> sell order to the ΟΑΣΗΣ. This is necessary given our previous discussion in Section 5.2.

Further, we assume each transaction happening at the same second, is part of a large order. For instance, the transactions with RecordId 15329, 15330, and 15331 in Table 6.2.1 are parts of one order. In particular, the size of the sell order which is in line for execution according to the time stamp is 500 shares, and it is matched with three smaller buy orders at the top of the limit order book (central book of pending round lot orders). We notice, that 310 shares are executed at GRD11.650, while the rest 190 are executed at a lower price, namely, at GRD11.640. This is the case because, there are 310 shares demanded for purchase at GRD11.650, while the next price at which there is some demand for shares to be purchased is two downticks lower, at GRD11640.

With this in mind, we conclude transactions 15570,15571, and 15572 are parts of one large buy order of 800 shares. There are only 300 shares offered at GRD11.685. These are taken up, the price moves an uptick,* and meets another limit sell order of 320 shares, which is absorbed too. Proceeding upwards, the spot price makes another uptick movement at GRD11.695 where the rest shares of the buy order are purchased. Consequently, the settlement price for this buy order is the weighed average price, where weights are the number of shares bought in each price. Thus, the settlement price is

$$[(300\text{x}11685 + 320\text{x}11690 + 180\text{x}11695) / 800] = 11689{,}25.$$

One should have noticed by now, that while in the Table 6.2.1 the spot price changes into the same second to find shares available for trading, the bid and ask prices do not seem to move accordingly. Particularly, the bid-ask spread changes to adjust to the next limit orders waiting at the top of the order book for execution, after the order (not the transaction) has been completed. In other words, the bid-ask spread appearing at the first transaction of second t is really the one as it is formed after the transactions at time t-1.

Furthermore, we exclude the transactions executed at the opening of the market, since they emerge in a different way from those executed in the rest of the day. While the orders in the main trading session are matched and executed according to price and time precedence, the orders executed at the opening follow a batch auction. Therefore we make the further assumption our investor is not going to submit an "at the open" order to liquidate his position.

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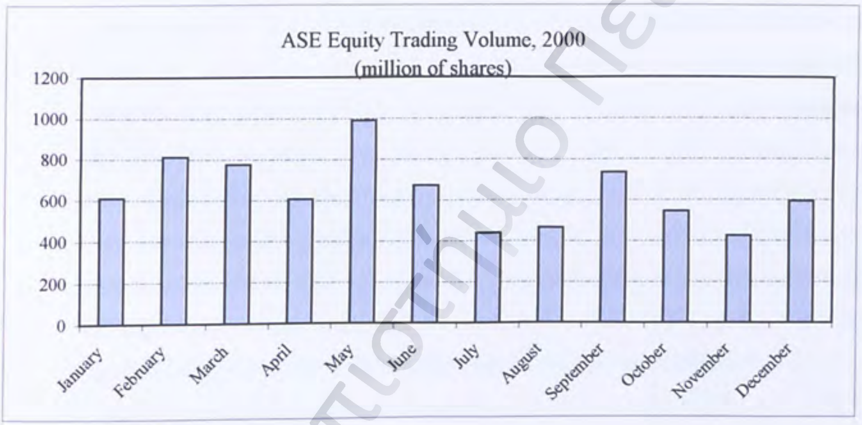
* Remember, that the allowed tick size for stock closing prices between GRD1.000-19.999 has been GRD5 until December 31st 2000

Table 6.2.1 A sample of he data used

| Date | RecordId | Symbol | Last | Volume | Bid | BidSize | Ask | AskSize | TimeStamp |
|---|---|---|---|---|---|---|---|---|---|
| 1/9/2000 | 15312 | ΠΙΣΤ | 11650 | 100 | 11650 | 310 | 11690 | 400 | 11:02:31 |
| 1/9/2000 | 15329 | ΠΙΣΤ | 11650 | 210 | 11650 | 310 | 11690 | 400 | 11:02:34 |
| 1/9/2000 | 15330 | ΠΙΣΤ | 11650 | 100 | 11650 | 310 | 11690 | 400 | 11:02:34 |
| 1/9/2000 | 15331 | ΠΙΣΤ | 11640 | 190 | 11650 | 310 | 11690 | 400 | 11:02:34 |
| 1/9/2000 | 15359 | ΠΙΣΤ | 11685 | 70 | 11640 | 810 | 11685 | 70 | 11:02:41 |
| 1/9/2000 | 15360 | ΠΙΣΤ | 11690 | 30 | 11640 | 810 | 11685 | 70 | 11:02:41 |
| 1/9/2000 | 15417 | ΠΙΣΤ | 11690 | 50 | 11640 | 810 | 11690 | 370 | 11:02:50 |
| 1/9/2000 | 15570 | ΠΙΣΤ | 11685 | 300 | 11660 | 100 | 11685 | 300 | 11:03:07 |
| 1/9/2000 | 15571 | ΠΙΣΤ | 11690 | 320 | 11660 | 100 | 11685 | 300 | 11:03:07 |
| 1/9/2000 | 15572 | ΠΙΣΤ | 11695 | 180 | 11660 | 100 | 11685 | 300 | 11:03:07 |
| 1/9/2000 | 15581 | ΠΙΣΤ | 11695 | 30 | 11660 | 100 | 11695 | 140 | 11:03:08 |
| 1/9/2000 | 15742 | ΠΙΣΤ | 11695 | 40 | 11660 | 100 | 11695 | 110 | 11:03:24 |

6.2.1 Diagram



## 6.3 DATA PROCESSING

### 6.3.1 First steps

We first compute the continuous compounded returns [ $\ln(S_t/S_{t-1})$ ] for the three shares chosen, through the three-month interval. We then exclude the overnight returns, since they are fictitious and often come up to 4%. They arise from the comparison of data between two trading days, while we are interested in intraday returns only, since every forward start put option is born and matures at the same trading day. Thus, we replace them with a randomly generated return. We use 20 adjacent observations (the last ten and the next ten of the replaced observation) to define a range, in which the random return is picked. By this way, the abnormal returns are avoided and the continuity of the data is guaranteed.

Since our goal is to observe the price impact initiated by the execution of a sell order, we use the tick classification rule, which is broadly used in intraday empirical analysis, in order to characterize a transaction as buy- or sell-initiated. Thus, we assume a transaction to be the execution of *one and only* sell order (meaning it is a one sell order matched with some smaller buy orders), when it produces a negative price return, while it is assumed *one and only* buy order to be executed (meaning that it is one buy order matched with some smaller sell orders), when it produces a positive price return. The tick classification rule is not in a position to distinguish the identity of the transactions with zero return but this weakness does not trouble us since the liquidity effect refers to transactions producing negative returns.

Furthermore, we select transactions executed at some discount related to the settlement price of the previous one.

We will now estimate three empirical measures of liquidity: the trade size, the first difference of the bid-ask spread, and the trade frequency. The reason we choose to work with them is they are most frequently used in real markets. Moreover, the first two are related to theoretical models trying to approach liquidity. We examine them in detail, below.

### 6.3.2 The "trade size" approach

The relation between trade size and the magnitude of price changes in financial markets has always been challenging. This relationship comes from the first family of the theoretical models. According to them, liquid markets are those which accommodate trading with the least effect on price. We have already discussed that the λ estimator these models suggest is derived from restrictive assumptions and composed by parameters that are very difficult to estimate in the real world. This is the reason λ is not used for empirical researches despite its significant theoretical interest.

Instead of trying to calculate λ, we will use an alternative argument according to which a market is quite liquid when large orders that can be information-initiated have a relatively little effect on the spot price of the stock. Thus, we will observe the relation between price and trade size for three listed companies. The arising results cannot and will not be generalized for all companies listed on A.S.E. Nevertheless, we get an idea how market variables interact in the Greek capital market.

We are going to observe the number of shares in each transaction that is an execution of one sell order, and watch the negative price impact it produced. Since, we already selected the transactions executed at some discount related to the previous one, we are going a step further and have a look at the descriptive statistics presented in Table 6.3.1.

In the time interval of August to October 2000, the mean trade size of sell orders amounts to 1182,23 shares for OTE, while for ΑΕΓΕΚ and ALPHA ΤΡΑΠΕΖΑ, it comes to 866,75 and 437,65 respectively. In addition, the most frequently met size for OTE is the amount of 1000 shares, while for ΑΕΓΕΚ and ALPHA ΤΡΑΠΕΖΑ, it lowers to 500 and 100 analogously. As one could imagine, OTE has the largest number of shares outstanding, namely 504 million common shares, 51,15% of which belong to the state and are not on free float. ALPHA ΤΡΑΠΕΖΑ follows with 162 mil. common shares issued, while, ΑΕΓΕΚ is far behind with 80 mil. shares outstanding. It is quite interesting to notice, that the average number of shares traded in each transaction for ALPHA ΤΡΑΠΕΖΑ, is almost half of the equivalent of ΑΕΓΕΚ, despite the fact that ΑΕΓΕΚ has half the shares issued by ALPHA ΤΡΑΠΕΖΑ, not to mention that 42% of these belong to three large shareholders who do not usually trade their shares.

A rational explanation to the above might be that ALPHA ΤΡΑΠΕΖΑ seems to have a large enough dispersion of its shares. Thus, we observe a large amount of relatively small orders during our study time. Furthermore, we should also take into account the fact that in the three-month period of which data are taken, the ASE

General Index was fluctuating around the level of 4.000 points, without a profound trend. Under these circumstances, we can imagine institutional investors to be rather defensive and to consciously keep a large percentage of their portfolios invested in "blue chips". Thus, we do not expect a large amount of shares of ALPHA ΤΡΑΠΕΖΑ on free float, which further explains its low average trade size.

We should focus on the impact created when there is lack of liquidity in the market. We have to define what we assume to be a rather illiquid market and then estimate the magnitude of this negative impact on the price of the stock. In this afford, we observe the cumulative relative frequency distribution of the sell orders' trade size, and select the transactions comprising the upper 5% of it.

Looking at the empirical distributions(Table 6.3.1), we see more than half of the transactions for ALPHA ΤΡΑΠΕΖΑ with negative return to refer to trade sizes up to 200 shares, while the 80% of them refer up to 500 shares, supporting the earlier conclusion of a well dispersed shareholder population. However, the most serious conclusion does not lie there. It is indeed the fact that the "critical value" –from now on, we call critical value the smallest number of shares lying into the upper 5% of the cumulative frequency distribution- seems to be rather low: for ΑΕΓΕΚ it amounts to 2.805 shares, for OTE is 4.995, while for ALPHA ΤΡΑΠΕΖΑ it hardly comes to the amount of 1.495 shares*.

Although there are some transactions involving the sale of 40.000, 60.000, or 100.000 shares, the trade size distribution for every share concerned is strongly negative skewed, since the great majority of transactions ( 80%) is not over 1500 shares. We have to admit these are not the results we expected beforehand: OTE and ALPHA ΤΡΑΠΕΖΑ are distinguished for their transaction volume, and ΑΕΓΕΚ stands out in the category of middle capitalization. Nevertheless, we do not have given other choice but to treat our data samples as cross sections of the populations, and use them to make estimations for the population means and variances.

We estimate the sample means and variances. The results are presented at Table 6.3.2.1. For ΑΕΓΕΚ, the "critical value" of the upper 5% region is 2805 shares while the number of transactions in the above region is 369. The sample mean is -0.0049, meaning the average liquidity effect (i.e. the negative price impact due to the

* Since the data are discrete concerning the number of shares traded, in addition to the fact that we refer to cumulative distributions, we choose those "critical values" which would determine the nearest to the upper 5% samples. The same procedure stands for the other two approaches, too.

execution of a large sell order) amounts to 0.49% of the spot price of the stock. Alternatively, we can the S/X comes up to 99,51%.

The implied assumption here is that as long as our data form a cross section of the population of negative returns involved with large orders, we can use the estimation of the sample mean and variance to make estimations for the population. Thus, the sample mean is assumed equal to the population one, as well constant and valid through out the life of the liquidity option.

Since the B-S formula requires the volatility per annum, we use the following formula to calculate it:

$$\sigma = \frac{s}{\sqrt{\tau}} \qquad (6.8)$$

where s stands for the standard deviation of the continuously compounded daily returns, and τ is the length of time interval in years. If the empirical standard deviations are taken from daily returns, we let τ=1/252 in order to take an estimation for volatility per annum. In our case, where the returns are intraday, we have to modify the formula as follows:

volatility per annum = (standard deviation of the continuously compounded intraday returns) x √ [(average daily number of transactions) x 252]

For example, the volatility per annum for ΑΕΓΕΚ, using the variance of the negative continuously compounded intraday returns is formed as:

$$\sigma = \sqrt{0{,}0000246}\; x \sqrt{\frac{369}{64} x 252}$$

$$= 0{,}004956\; x \sqrt{\frac{369}{64} x 252} = 0{,}1889$$

Perhaps, we should explain here, we used the estimation of the square root of variance of the negative continuously compounded intraday returns as the empirical intraday stock volatility (concerning the negative returns). Also, 369 is the number of observations included in the upper 5% sample we selected earlier, while 64 are the trading days in the three-month period we examined. The inherent assumptions here are that, the stock volatility is constant during the life of the liquidity option, and it is satisfactorily estimated from historical data.

By making the above calculations, we end up with an estimation of the liquidity effect and the volatility per annum for the three listed stocks (presented at Table 6.3.2.1). What we observe is that the liquidity effects seem rather small as a percentage of the spot price of the stock since they amount to 0,49% for ΑΕΓΕΚ, 0,127% for ALPHA ΤΡΑΠΕΖΑ and 0,133% for ΟΤΕ.

A first thought was to attribute these results to the percentage we used to select the samples; it seems to be rather large. Thus, we decided to use a smaller one, we examined our data and selected the transactions composing the upper 1,5% of the empirical distributions.

Thus, we take as "critical values" 5005 shares for ΑΕΓΕΚ, 3000 for ALPHA ΤΡΑΠΕΖΑ, and 9005 for ΟΤΕ (Table 6.3.1.). These critical values are significantly higher than the previous ones: i.e. ALPHA ΤΡΑΠΕΖΑ has doubled its amount. Using the same methodology as before, we take estimations for the liquidity effect and the volatility per annum concerning the three shares. The results are presented at the Table 6.3.2.2. Comparing the results with those of the upper 5%, we would say the liquidity effect for ΑΕΓΕΚ is the one having most sharply risen after the alteration (0,64% from 0,49%). The changes in liquidity effects related to the other two stocks are not so serious, the corresponding one for ALPHA ΤΡΑΠΕΖΑ reached to 0,15% from 0,13%, while for ΟΤΕ it came to 0,14% from 0,13%.

What we clearly observe is that liquidity effects for ΑΕΓΕΚ, corresponding to results of the upper 5% and 1,5% of its cumulative frequency distribution, are larger than the ones ALPHA ΤΡΑΠΕΖΑ and ΟΤΕ displayed. Since ΑΕΓΕΚ has the smallest number of shares on free float, we might think the smaller the number of shares on free float, the larger the price impact of a large sell order. One could say, a negative relationship seems to exist between the number of shares on free float, and the magnitude of the liquidity effect.

Nevertheless, we have the impression that the market didn't reveal all its dynamics in this short time interval, especially as far as it concerns ΟΤΕ and ALPHA ΤΡΑΠΕΖΑ, meaning we might not observe really large transactions related to these stocks.

We will later discuss the prices of the daily forward start put options and liquidity options these estimations entail. For the moment, we have to estimate the liquidity effects with the second measure of liquidity: the difference of the bid-ask spread between two succesive transactions.

6.3.3 The "first difference of bid-ask spread" approach

The second family of the theoretical models of liquidity proposes as a measure of liquidity the bid-ask spread quoted in the market. By this point of view, the smaller the size of the bid-ask spread, the more liquid the market is.

We estimate the liquidity effect by using the change in the magnitude of the bid-ask spread between two successive transactions as a measure of liquidity. We decided so, in order to observe the impact a large sell order will have in the quotation of the bid-ask spread.

Before proceeding further, we should discuss an issue arisen in our effort to take an estimation of liquidity effect, using the first difference of bid-ask spread [Δ(bid-ask spread)]. In the three month period we examined, we observed the spot price of ALPHA ΤΡΑΠΕΖΑ reached the daily-ceiling price fluctuation of 12% twice on 8th September 2000, while that of ΑΕΓΕΚ did the same thing once, on 6th October 2000. When the daily-ceiling price fluctuation is reached, the execution of buy orders is halted until the buy orders that were to be executed are withdrawn or modified at a lower desired trading price, while the execution of sell orders is not affected at all, they keep executing according their time stamp. As long as it takes the buy orders to be modified, there is no ask quoted (in particular the quote is 0), and the bid-ask spread broadens fictitiously and results in huge jump in its first difference. Therefore, we decided to exclude these transactions from our data set in order to avoid misleading results.

Looking at the descriptive statistics of the sell orders' intra-day data, we observe the most usually met change in bid-ask spread is zero (Table 6.3.1). On the other hand, on average, the bid-ask spread seems to increase slightly with the execution of a sell order. The historical data concerning ALPHA ΤΡΑΠΕΖΑ display a relatively stronger relation than the equivalent estimations for the other two firms, in the time interval available.

Again, we define the upper 5% and 1,5% of our data as cutoff points. Thus, we select the transactions with first difference of bid-ask spread equal to or above of GRD 15 for ΑΕΓΕΚ, GRD 25 for ALPHA ΤΡΑΠΕΖΑ, and GRD 10 for OTE, in order to create the samples that will determine the size of the liquidity effect according the upper 5% criterion, while for the 1,5% criterion, the minimum included bid-ask spread difference amounts to 20 for ΑΕΓΕΚ, 45 for ALPHA ΤΡΑΠΕΖΑ, and 20 for ΟΤΕ.

We observe that ALPHA ΤΡΑΠΕΖΑ exhibits relatively larger jumps in the bid-ask spread quotes for successive transactions although it has the largest number of transactions of the three listed companies in the three-month period(Table 6.3.1).

As before, we assume these samples to be cross sections of the population of sell orders that create large bid-ask spread differences, and estimate the average negative returns. Next, using the same methodology and assumptions as in the previous approach, we work out estimations for the volatility per annum for the three listed stocks. The results are presented in the Table 6.3.2.1 and 6.3.2.2.

Again, we find the historical estimates of the negative returns rather low. The largest liquidity effects are observed in ΑΕΓΕΚ(-0,71% and –0,79%), which exhibits the largest share volatility as well(16% and 13% per annum).

### 6.3.4 The "trade frequency" approach

According to this approach, the more frequent the order submission for listed companies' shares is, the more liquid the stock market is. This viewpoint has not been investigated to such an extent as the previous ones. A few empirical analyses, however, have generally concluded that time does play a role to the price formation, consequently to the price return, but it is not clear yet how large this role is.

Nevertheless, we decide to examine our data against the time frequency and follow the same methodology as before, to take an idea of the role, time frequency plays in the Greek capital market. We choose transactions comprising the upper 5% and 1,5% of the empirical cumulative relative frequency distribution of the time intervening between successive sell orders in order to form our samples. Continuing, we take an estimation of the average negative return involved in the execution of the particular sell orders and assuming that the samples constitute cross sections of the populations, we reduce the results to the population means and variances.

Table 6.3.1 presents the descriptive statistics for the sell order intraday data, and confirm our expectations. According to them, ΑΕΓΕΚ exhibits on average, the larger time intervals between successive transactions (39 seconds), while the sell transactions for ΟΤΕ and ALPHA ΤΡΑΠΕΖΑ occur, on average, with almost the same time frequency( every 20 and 21 seconds on average, respectively). The largest observations are found in ΑΕΓΕΚ, where as "critical value" we choose the time interval of 2'25" to take a sample composing the upper 5% of the cumulative relative frequency function, while for the sample composing the 1,5% the minimum time interval comes to 3'59". For the other two shares, the cutoff points seem to be lower: the 5% critical value comes to 1'15" for ALPHA ΤΡΑΠΕΖΑ and 1'13" for OTE, while the 1,5% one is 2'01" for ALPHA ΤΡΑΠΕΖΑ, and 1'58" for OTE.

Finally, we estimate the liquidity effects and the stock volatilities per annum for the three shares we examine. Again, it is ΑΕΓΕΚ displaying the largest liquidity effects (0,48% and 0,49%), even if these amounts are not large in absolute terms. ΑΕΓΕΚ also displays the largest stock volatility estimates.

In the next session, we move a step further and estimate the prices for the one-day forward option as well for the one-year liquidity option.

Table 6.3.1 Descriptive statistics and Relative Cumulative Frequency Distributions of the sell orders' intraday data all through the three-month period, categorized by Trade Size, Δ(bid-ask spread), and Trade Frequency (Δt)

*Trade Size*

| | ΑΕΓΕΚ | ALPHA | OTE |
|---|---|---|---|
| Mean | 866,75037 | 437,6486 | 1182,233 |
| Median | 500 | 200 | 500 |
| Mode | 500 | 100 | 1000 |
| Variance | 2853282,7 | 772411,5 | 8612237 |
| Total number of observations | 7407 | 14821 | 13195 |
| Maximum observation | 60000 | 40000 | 107350 |
| Minimum observation | 10 | 10 | 10 |
| Confidence interval (95,0%) | 38,474255 | 14,15042 | 50,07732 |

*First difference of the bid -ask spread between two successive transactions*

| | ΑΕΓΕΚ | ALPHA | OTE |
|---|---|---|---|
| Mean | 0,36452 | 0,7098037 | 0,2171277 |
| Median | 0 | 0 | 0 |
| Mode | 0 | 0 | 0 |
| Variance | 46,734512 | 215,9064 | 44,69857 |
| Total num.of obser. | 7407 | 14821 | 13195 |
| Max.observation | 70 | 190 | 125 |
| Min.observation | -70 | -300 | -140 |
| Conf.Interval(95%) | 0,1557101 | 0,2365798 | 0,1140853 |

*Trade Frequency (Δt between two succestive transactions)*

| | ΑΕΓΕΚ | ALPHA | OTE |
|---|---|---|---|
| Mean | 0:00:39 | 0:00:21 | 0:00:20 |
| Median | 0:00:19 | 0:00:10 | 0:00:10 |
| Mode | 0:00:01 | 0:00:01 | 0:00:01 |
| Variance | 5,014E-07 | 1,315E-07 | 1,243E-07 |
| Total num.of obser. | 7407 | 14821 | 13195 |
| Max.observation | 0:23:41 | 0:22:05 | 0:23:23 |
| Min.observation | 0:00:01 | 0:00:01 | 0:00:01 |
| Conf.Interval(95%) | 1,613E-05 | 5,838E-06 | 6,016E-06 |

*Cumulative Relative Frequency*

| *trade size* | *ΑΕΓΕΚ* | *ALPHA* | *OTE* |
|---|---|---|---|
| 200 | 29,16% | 54,44% | 34,99% |
| 500 | 58,78% | 79,57% | 56,87% |
| 1300 | 84,22% | 94,43% | 78,31% |
| 1490 | 85,38% | 94,85% | 79,18% |
| 1700 | 87,96% | 95,86% | 81,88% |
| 2800 | 95,02% | 98,40% | 89,84% |
| 2995 | 95,17% | 98,43% | 90,08% |
| 3000 | 96,41% | 98,77% | 92,27% |
| 4990 | 97,88% | 99,26% | 94,68% |
| 4995 | 97,88% | 99,26% | 94,68% |
| 5000 | 98,85% | 99,62% | 97,23% |
| 9000 | 99,45% | 99,86% | 98,52% |
| > | 100,00% | 100,00% | 100,00% |

*Cumulative Relative Frequency*

| *Δ(bid-ask spread)* | *ΑΕΓΕΚ* | *ALPHA* | *OTE* |
|---|---|---|---|
| -15 | 2,65% | 8,35% | 2,44% |
| -10 | 6,78% | 14,18% | 5,56% |
| -5 | 18,74% | 24,55% | 16,79% |
| 0 | 75,86% | 67,18% | 79,29% |
| 5 | 92,26% | 82,81% | 94,19% |
| 10 | 96,88% | 90,51% | 97,64% |
| 15 | 98,43% | 93,31% | 98,57% |
| 20 | 99,19% | 95,70% | 99,25% |
| 40 | 99,89% | 98,79% | 99,86% |
| > | 100,00% | 100,00% | 100,00% |

*Cumulative Relative Frequency*

| *Δt* | *ΑΕΓΕΚ* | *ALPHA* | *OTE* |
|---|---|---|---|
| 0:00:01 | 4,50% | 8,53% | 7,86% |
| 00:00:02-00:00:10 | 30,63% | 47,43% | 47,74% |
| 00:00:11-00:00:20 | 52,60% | 69,89% | 70,56% |
| 00:00:21-00:00:45 | 75,19% | 87,39% | 88,44% |
| 00:00:46-00:01:11 | 84,92% | 94,50% | 94,88% |
| 0:01:12 | 85,18% | 94,67% | 95,07% |
| 00:01:13-00:01:14 | 85,53% | 95,03% | 95,35% |
| 00:01:15-00:01:57 | 92,67% | 98,37% | 98,46% |
| 00:01:58-00:02:00 | 92,97% | 98,46% | 98,54% |
| 00:02:01-00:02:24 | 94,95% | 99,12% | 99,08% |
| 00:02:25-00:03:58 | 98,49% | 99,89% | 99,87% |
| > | 100,00% | 100,00% | 100,00% |

6.3.2.1 Final Results of the Empirical Analysis [upper 5%]

| | Trade size | | | Δ(bid-ask spread) | | | Δt | | |
|---|---|---|---|---|---|---|---|---|---|
| | *ΑΕΓΕΚ* | *ALPHA BANK* | *OTE* | *ΑΕΓΕΚ* | *ALPHA BANK* | *OTE* | *ΑΕΓΕΚ* | *ALPHA BANK* | *OTE* |
| *Average Negative Return* | -0,49% | -0,13% | -0,13% | -0,71% | -0,22% | -0,19% | -0,48% | -0,12% | -0,12% |
| *Liquidity Effect* | 0,49% | 0,13% | 0,13% | 0,71% | 0,22% | 0,19% | 0,48% | 0,12% | 0,12% |
| *S/X ratio* | 99,51% | 99,87% | 99,87% | 99,29% | 99,78% | 99,81% | 99,52% | 99,88% | 99,88% |
| *Empirical Intraday Stock Volatility(1)* | 0,50% | 0,16% | 0,15% | 0,54% | 0,21% | 0,18% | 0,48% | 0,13% | 0,11% |
| *Number of Sample Observations (2)* | 369 | 764 | 702 | 231 | 637 | 766 | 369 | 737 | 651 |
| *Stock Volatility per Annum (3)* | 18,89% | 8,71% | 7,81% | 16,16% | 10,29% | 10,14% | 18,14% | 7,04% | 5,73% |
| *Risk Free Rate Annually Compounded (4)* | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% |
| *Equiv.Cont.Compounded Risk Free Rate* | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% |
| *Discount Rate (5)* | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% |
| $\tau 1$ | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 |
| $\tau 2$ | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 |
| $d1$ | -0,39863 | -0,20408 | -0,24110 | -0,67911 | -0,31799 | -0,26984 | -0,40706 | -0,23819 | -0,29838 |
| $d2$ | -0,41053 | -0,20957 | -0,24601 | -0,68929 | -0,32447 | -0,27623 | -0,41849 | -0,24263 | -0,30198 |
| $N(-d1)$ | 0,65492 | 0,58085 | 0,59526 | 0,75147 | 0,62475 | 0,60636 | 0,65802 | 0,59413 | 0,61729 |
| $N(-d2)$ | 0,65929 | 0,58300 | 0,59716 | 0,75468 | 0,62721 | 0,60881 | 0,66220 | 0,59585 | 0,61867 |
| *Price of 1-Day Forward Start Option (p/X) (6)* | **0,75%** | **0,28%** | **0,26%** | **0,84%** | **0,38%** | **0,35%** | **0,73%** | **0,24%** | **0,20%** |
| *(p/X) / Liquidity Effect (7)* | 1,524 | 2,211 | 1,968 | 1,192 | 1,697 | 1,873 | 1,505 | 1,963 | 1,682 |

*Price of 1-Year Liquidity Option (8)*

| Trade size | | | Δ(bid-ask spread) | | | Δt | | |
|---|---|---|---|---|---|---|---|---|
| *ΑΕΓΕΚ* | *ALPHA BANK* | *OTE* | *ΑΕΓΕΚ* | *ALPHA BANK* | *OTE* | *ΑΕΓΕΚ* | *ALPHA BANK* | *OTE* |
| $0,0075\sum_{t=1/252}^{1} Xe^{-0,0504}$ | $0,0028\sum_{t=1/252}^{1} Xe^{-0,0504}$ | $0,0026\sum_{t=1/252}^{1} Xe^{-0,0504}$ | $0,0084\sum_{t=1/252}^{1} Xe^{-0,0504}$ | $0,0038\sum_{t=1/252}^{1} Xe^{-0,0504}$ | $0,0035\sum_{t=1/252}^{1} Xe^{-0,0504}$ | $0,0073\sum_{1/252}^{1} Xe^{-0,0504}$ | $0,0024\sum_{t=1/252}^{1} Xe^{-0,0504}$ | $0,002\sum_{t=1/252}^{1} Xe^{-0,0504}$ |

(1) Empirical intraday stock volatility is assumed to be constant and equal to the standard deviation of the negative continuously compounded intraday returns of the selected sample
(2) Number of the sample observations comprising the upper 5% of the empirical distributions
(3) Stock Volatility per Annum=(standard deviation of the negative continuously compounded intraday returns of the sample) x √ [(number of transactions of the sample/ number of trading days in the three-month period) x number of trading days per annum]
(4) Net Return on 12 mounth Greek Treaury Bill, time to maturity 1 year, date of issue 27/10/2000
(5) Discount Rate is the equivalent continuously compounded risk free rate+20b.p rik premium
(6) Price of 1-Day Forward Option as a percentage of the spot price of the stock
(7) Price of 1-Day Forward Option as a percentage of the spot price of the stock devided by the amount of Liquidity Effect
(8) Price of 1-Year Liquidity Option displayed as a function of the spot price of the stock

6.3.2.2 Final Results of the Empirical Analysis [upper 1,5%]

| | Trade size | | | Δ(bid-ask spread) | | | Δt | | |
|---|---|---|---|---|---|---|---|---|---|
| | ΑΕΓΕΚ | ALPHA BANK | OTE | ΑΕΓΕΚ | ALPHA BANK | OTE | ΑΕΓΕΚ | ALPHA BANK | OTE |
| *Average Negative Return* | -0,64% | -0,15% | -0,14% | -0,79% | -0,29% | -0,29% | -0,49% | -0,13% | -0,13% |
| *Liquidity Effect* | 0,64% | 0,15% | 0,14% | 0,79% | 0,29% | 0,29% | 0,49% | 0,13% | 0,13% |
| *S/X ratio* | 99,36% | 99,85% | 99,86% | 99,21% | 99,71% | 99,71% | 99,51% | 99,87% | 99,87% |
| *Empirical Intraday Stock Volatility(1)* | 0,77% | 0,20% | 0,14% | 0,63% | 0,29% | 0,25% | 0,42% | 0,16% | 0,13% |
| *Number of Sample Observations (2)* | 85 | 232 | 195 | 116 | 179 | 189 | 109 | 218 | 199 |
| *Stock Volatility per Annum (3)* | 14,17% | 6,19% | 3,98% | 13,39% | 7,72% | 6,71% | 8,61% | 4,76% | 3,73% |
| *Risk Free Rate Annually Compounded (4)* | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% | 4,96% |
| *Equiv.Cont.Compounded Risk Free Rate* | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% | 4,84% |
| *Discount Rate (5)* | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% | 5,04% |
| $\tau 1$ | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 | 1/252 |
| $\tau 2$ | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 | 1/365 |
| $d1$ | -0,70331 | -0,34906 | -0,48575 | -0,92519 | -0,56998 | -0,65015 | -0,88010 | -0,40291 | -0,50494 |
| $d2$ | -0,71224 | -0,35296 | -0,48826 | -0,93362 | -0,57484 | -0,65437 | -0,88552 | -0,40591 | -0,50729 |
| $N(-d1)$ | 0,75907 | 0,63648 | 0,68643 | 0,82257 | 0,71565 | 0,74220 | 0,81060 | 0,65649 | 0,69320 |
| $N(-d2)$ | 0,76184 | 0,63794 | 0,68732 | 0,82475 | 0,71730 | 0,74356 | 0,81206 | 0,65759 | 0,69403 |
| *Price of 1-Day Forward Start Option (p/X) (6)* | **0,76%** | **0,23%** | **0,17%** | **0,86%** | **0,36%** | **0,34%** | **0,53%** | **0,19%** | **0,16%** |
| *(p/X) / Liquidity Effect (7)* | 1,174 | 1,555 | 1,276 | 1,084 | 1,249 | 1,180 | 1,087 | 1,412 | 1,248 |

*Price of 1-Year Liquidity Option (8)*

| Trade size | | | Δ(bid-ask spread) | | | Δt | | |
|---|---|---|---|---|---|---|---|---|
| ΑΕΓΕΚ | ALPHA BANK | OTE | ΑΕΓΕΚ | ALPHA BANK | OTE | ΑΕΓΕΚ | ALPHA BANK | OTE |
| $0{,}0076\sum_{t=1/252}^{1} Xe^{0{,}0504t}$ | $0{,}0023\sum_{t=1/252}^{1} Xe^{-0{,}0504t}$ | $0{,}0017\sum_{t=1/252}^{1} Xe^{0{,}0504t}$ | $0{,}0086\sum_{t=1/252}^{1} Xe^{-0{,}0504t}$ | $0{,}0036\sum_{t=1/252}^{1} Xe^{-0{,}0504t}$ | $0{,}0034\sum_{t=1/252}^{1} Xe^{0{,}0504t}$ | $0{,}0053\sum_{t=1/252}^{1} Xe^{-0{,}0504t}$ | $0{,}0019\sum_{t=1/252}^{1} Xe^{-0{,}0504t}$ | $0{,}0016\sum_{t=1/252}^{1} Xe^{-0{,}0504t}$ |

(1) Empirical intraday stock volatility is assumed to be constant and equal to the standard deviation of the negative continuously compounded intraday returns of the selected sample
(2) Number of the sample observations that comprise the upper 1,5% of the empirical distributions
(3) Stock Volatility per Annum=(standard deviation of the negative continuously compounded intraday returns of the sample) x √ [(number of transactions of the sample/ number of trading days in the three-month period) x number of trading days per annum]
(4) Net Return on 12 mounth Greek Treaury Bill, time to maturity 1 year, date of issue 27/10/2000
(5) Discount Rate is the equivalent continuously compounded risk free rate+20b.p rik premium
(6) Price of 1-Day Forward Option as a percentage of the spot price of the stock
(7) Price of 1-Day Forward Option as a percentage of the spot price of the stock devided by the amount of Liquidity Effect
(8) Price of 1-Year Liquidity Option displayed as a function of the spot price of the stock

## 6.4 EMPIRICAL RESULTS

### 6.4.1 Option Prices

Until now, we have worked out estimates for liquidity effect and volatility. Assuming these estimates will remain constant and valid through out the life of the liquidity option, we now turn to the pricing of the daily forward starting European put option.

All necessary parameters for the B-S formula as well as the final prices of the options are exhibited at the Tables 6.3.2.1 and 6.3.2.2. We set the time to maturity of the liquidity option to be one year, starting on 1st November 2000. We therefore need the 1-year risk free rate for the calculation of the price of the liquidity option. We use the net yield to maturity of Greek Treasury bill with maturity one year, issued on 27th October 2000, the nearest issuance to the beginning of our liquidity option. This amounts to 4,96%, or 4,84% on a continuously compounded basis.

We estimate the price of the liquidity option as the sum of the discounted prices of the daily forward starting put options. As discount rate, we use the continuously compounded risk free rate plus as a risk premium of 20b.p.( +0,2%), since the firms, for which we estimate the option prices, have a nonzero probability of default. The magnitude of the risk premium is a subjective decision, and can be revised as necessary.

ΑΕΓΕΚ exhibits the highest forward start option prices for all the approaches used (about 0,8% of the spot price of the stock). ALPHA ΤΡΑΠΕΖΑ and ΟΤΕ follow with forward start option prices about 0,2-0,3%.

We observe that after the reduction of the percentage taken as cutoff point, half of the forward start option prices decline. This is the case, because the volatility is reduced, due to the sample observations' decrease, at such an extent that overcomes the liquidity effect rise.

A significant feature of the options is that the price of the daily forward start option seems to be significantly higher than the liquidity effect it aims to cover (sometimes it is twice the percentage of the liquidity effect). In particular, the "trade size" approach exhibits the highest option prices as percentages of the liquidity effect (Table 6.3.2.1-6.3.2.2). This fact justifies our claim that the liquidity option should be given for free to the large investors. Otherwise, no investor would decide to buy a liquidity option and pay its premium, since the payoff it provides is significantly smaller than the initial outflow.

6.4.2. Inter-temporal Analysis of Liquidity Regarding the Three Shares Available.

Looking at the scatter plots (6.4.2.1-6.4.2.9), we observe that although the range of returns has not changed significantly through the period, the relatively large transactions are executed with greater frequency, and without producing large returns in September. This ability of the market to absorb relatively large transactions without producing large returns is a sign it is relatively more liquid in September than in the other months.

Approaching liquidity by the difference in the bid-ask spread between two successive transactions (Scatter plots 6.4.2.10-6.4.2.18), we reach a similar to the above conclusion regarding our firms: we observe the market absorbed relatively large bid-ask spread differences which occurred in September quite harmlessly, without producing large impact on returns. Thus, market seems to be more liquid in September, in comparison with the other two months.

Concerning the trade frequency approach, the results are rather peculiar. Looking at the scatter plots 6.4.2.19 – 6.4.2.27, we observe that, for ΑΕΓΕΚ, liquidity seems to be at the same level through out the three-month period, since the time intervals between successive transactions in relation to the returns, are distributed similarly amongst the months. As to ALPHA ΤΡΑΠΕΖΑ and ΟΤΕ, although the range of time intervals does not seem to change during the period, the range of returns seems to increase slightly in September. The strangest thing is these unusually large positive and negative returns are referred to transactions settled within a short time interval from the previous transaction (Δt close to zero). This behavior is a rather bad signal for liquidity regarding these two shares, but we hesitate to characterize the market in September as relatively less liquid in comparison with the other months.

As a general conclusion we could say it seems the empirical measures of liquidity do not always agree on the characterization of the status of the market.

Diagram 6.4.2.1 Trade size versus return for AEΓEK. August 2000

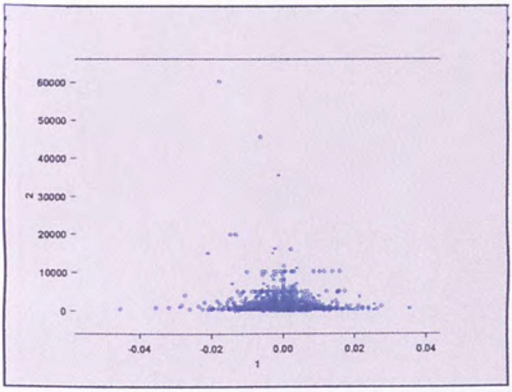



Diagram 6.4.2.2 Trade size versus return for AEΓEK September 2000

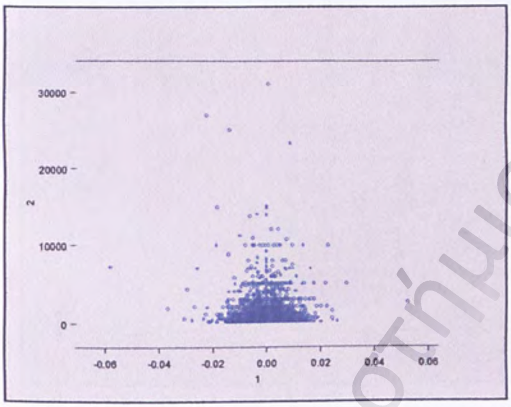



Diagram 6.4.2.3 Trade size versus return for AEΓEK October 2000

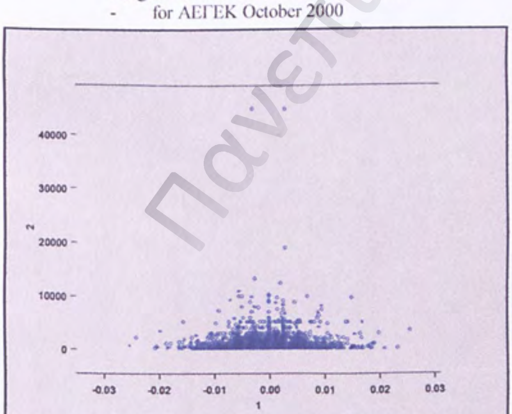



Diagram 6.4.2.4 Trade size versus return for ALPHA BANK, August 2000

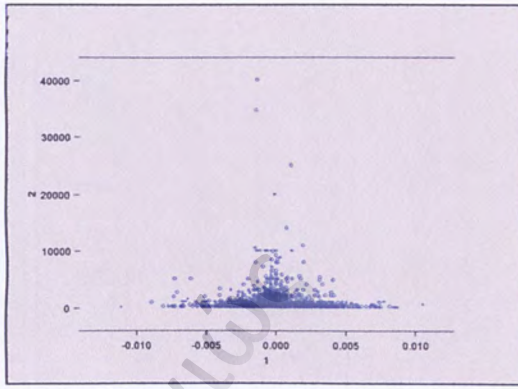



Diagram 6.4.2.5 Trade size versus return for ALPHA BANK September 2000

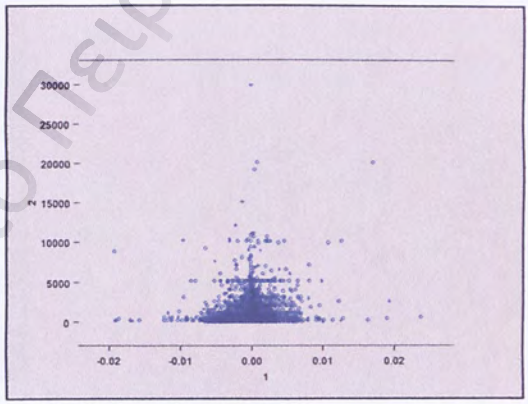



Diagram 6.4.2.6 Trade size versus return for ALPHA BANK October 2000

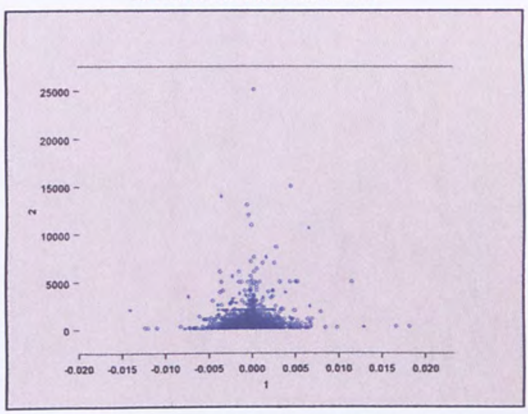


Diagram 6.4.2.7 Trade size versus return for OTE
August 2000

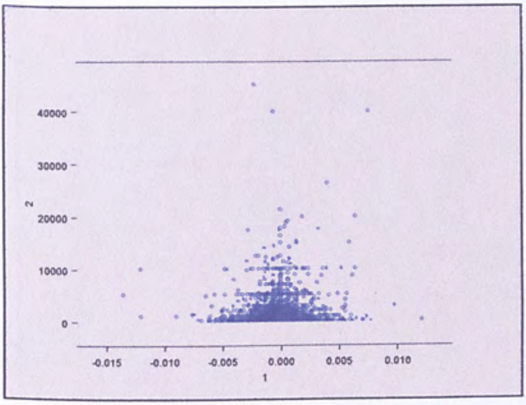



Diagram 6.4.2.8 Trade size versus return for OTE
September 2000

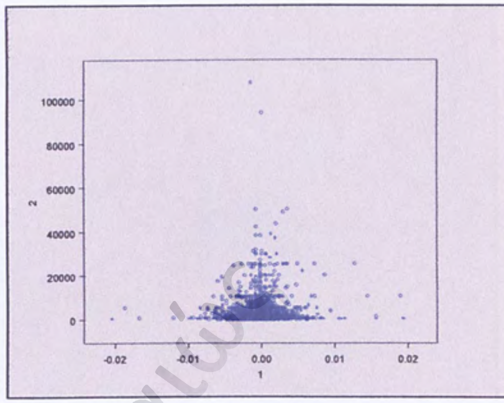



Diagram 6.4.2.9 Trade size versus return for OTE
October 2000

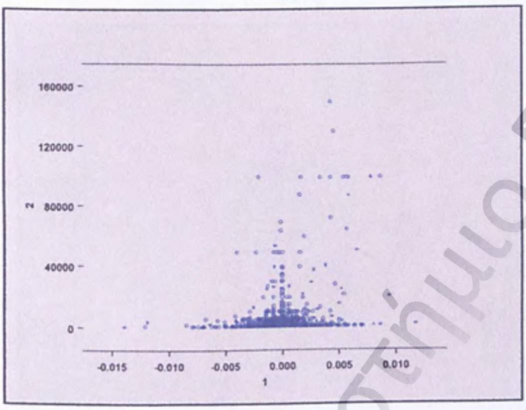


Diagram 6.4.10 First Difference of bid-ask spread versus Return for AEΓEK, August 2000

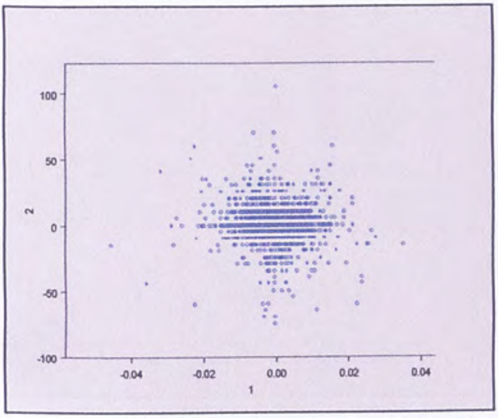



Diagram 6.4.2.11First Difference of bid-ask spread versus Return for AEΓEK, September 2000

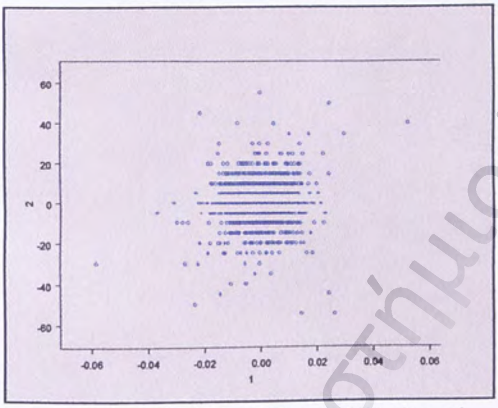



Diagram 6.4.2.12 First Difference of bid-ask spread versus Return for AEΓEK, October 2000

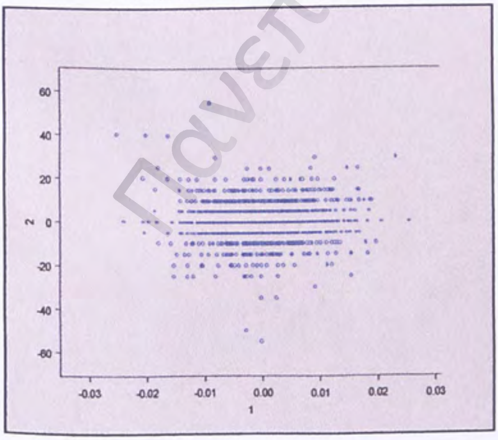



Diagram 6.4.2.13 First Difference of bid-ask spread versus Return for ALPHA, August 2000

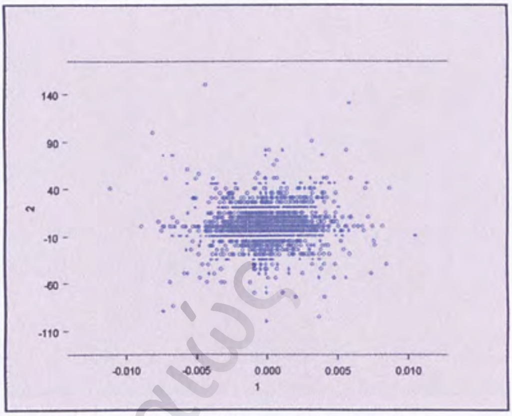



Diagram 6.4.2.14 First Difference of bid-ask spread versus Return for ALPHA, September 2000

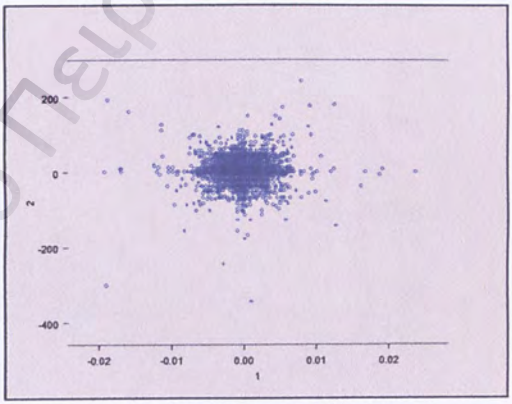



Diagram 6.4.2.15 First Difference of bid-ask spread versus Return for ALPHA, October 2000

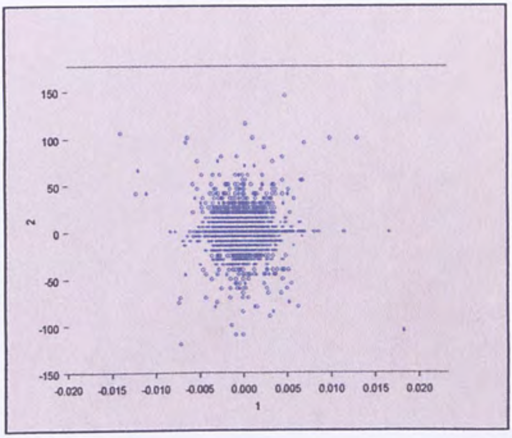


Diagram 6.4.2.16 First Difference of bid-ask spread versus Return for OTE, August 2000

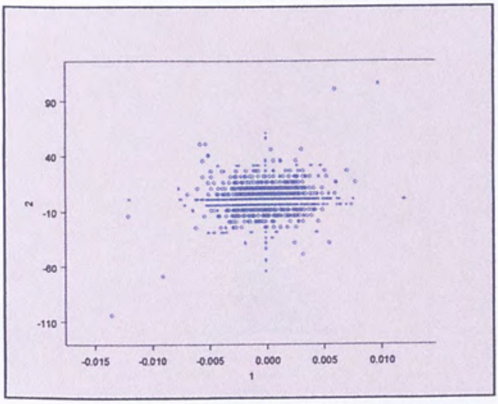



Diagram 6.4.2.17 First Difference of bid-ask spread versus Return for OTE, September 2000

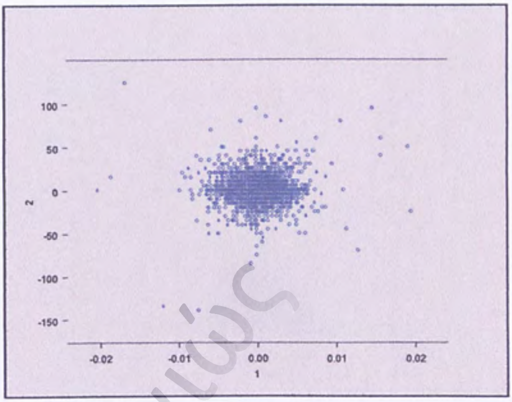



Diagram 6.4.2.18 First Difference of bid-ask spread versus Return for OTE, October 2000

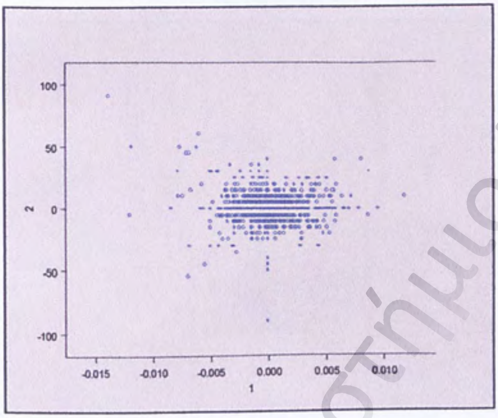


Diagram 6.4.2.19 Trade Frequency (Δt) versus Return for ΑΕΓΕΚ, August 2000

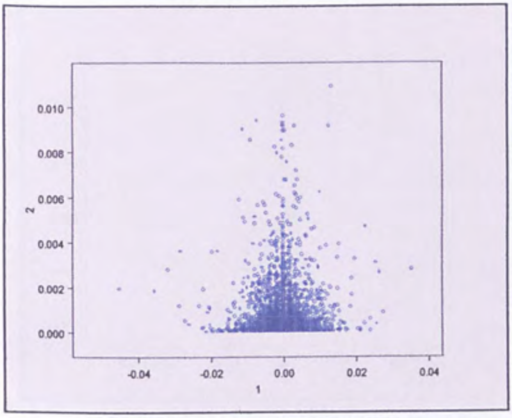



Diagram 6.4.2.20 Trade Frequency (Δt) versus Return for ΑΕΓΕΚ, September 2000

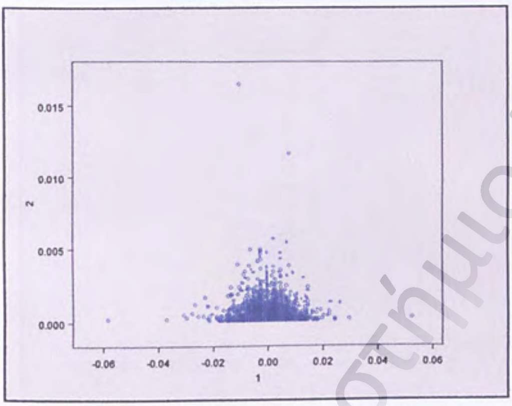



Diagram 6.4.2.21Trade Frequency (Δt) versus Return for ΑΕΓΕΚ, October 2000

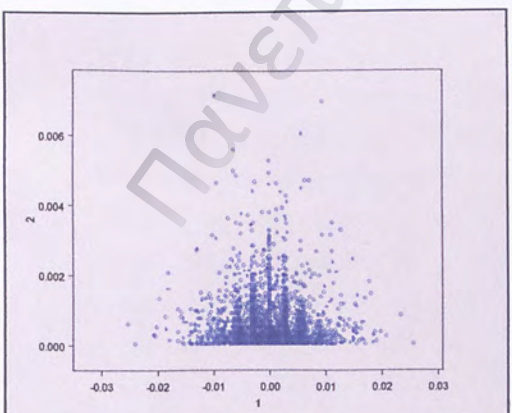



Diagram 6.4.2.22 Trade Frequency (Δt) versus Return for ALPHA, August 2000

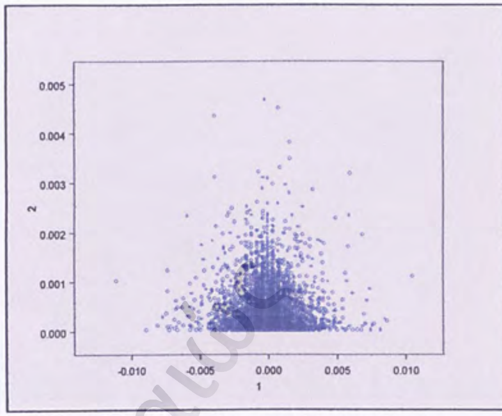



Diagram 6.4.2.23 Trade Frequency (Δt) versus Return for ALPHA, September 2000

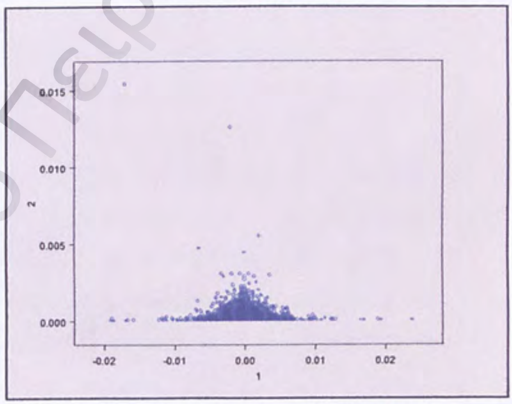



Diagram 6.4.2.24 Trade Frequency (Δt) versus Return for ALPHA, October 2000

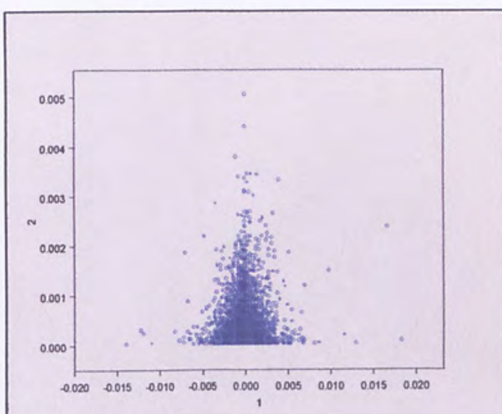


Diagram 6.4.2.25 Trade Frequency (Δt) versus Return for OTE, August 2000

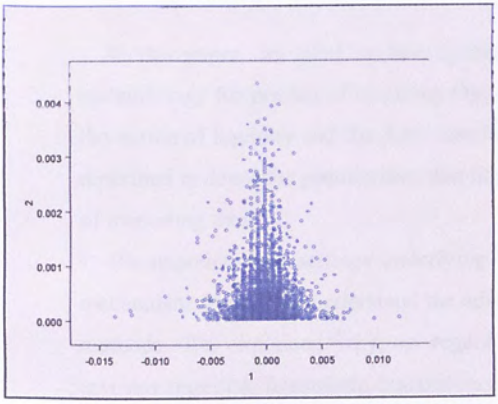



Diagram 6.4.2.26 Trade [illegible] for OTE, [illegible]

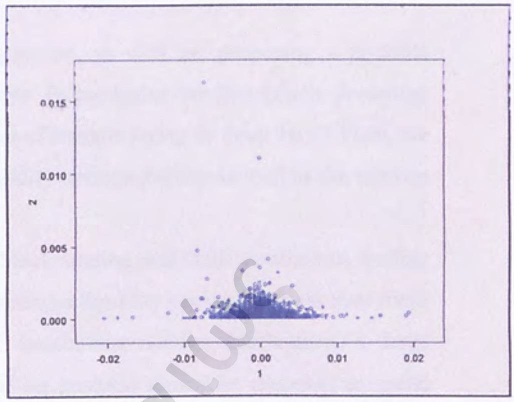
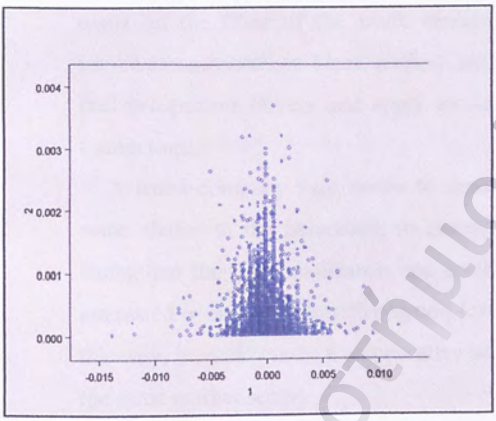



Diagram 6.4.2.27 Trade Frequency (Δt) versus Return for OTE, October 2000



## 7. CONCLUSIONS

In this paper, we tried explaining the notion, as well as, proposing a possible methodology for pricing of Liquidity Options. In particular, we first briefly presented the notion of liquidity and the three families of models trying to describe it. Then, we described in detail the peculiarities that liquidity options display as well as the reasons of marketing them.

We examined the settings underlying block trading and ASE continuous trading mechanism, in order to understand the advantages liquidity options provide over these methods. We explained why, as regards continuous auction mechanism, a large investor requiring immediate liquidation of his position should be prepared to spend some time, and possibly suffer a "haircut" of his position, in order to sell the shares he owns on the floor of the stock exchange. On the other hand, we discussed the implications related to block trading: our investor should again spend some time to find prospective buyers and apply to ASE for permission for the execution of the transaction.

A listed company may desire to repurchase part of its stock in order to provide some shares to the personnel, to change its capital structure, to write off loss, to strengthen the price resistance and avoid hostile takeovers. A company would be interested in issuing a liquidity option for all the above reasons, as well as because by this way, it would create a comparative advantage for its own stock, over the others in the same market sector.

The liquidity option can be viewed as a series of European daily forward start put options, or in another way, as an American put option the strike price of which changes every day. We adopt the first approach in this paper. The second approach is quite challenging and is open to future research.

A distinctive feature of the liquidity option is that its exercise price is not settled at the time the contract is made, but is always equal to the spot price of the stock. So, the value of each daily forward start put option seems to be zero in first place. It is not so in reality since, its payoff equals the liquidity effect (the negative price impact) an investor would have to suffer if he did not own such an option.

We used intra-day data for August, September, and October 2000 for three listed common stocks: ΑΕΓΕΚ, ΟΤΕ, ALPHA ΤΡΑΠΕΖΑ. We estimated liquidity effects using three empirical measures of liquidity: the trade size, the first difference of the bid-ask spread[Δ(bid-ask spread)], and the trade frequency(Δt), and then worked out a price for the forward start option and, hence, for the liquidity option.

If we were in the large investors' shoes, we would be interested in option prices taken from the trade size approach, since the issue worrying the large investor the most is the discount he has to face in order to liquidate immediately his position. An organized stock exchange examining the reasons for allowing liquidity options issuance would demand a more spherical analysis and use many different approaches, including ours, to assess liquidity option price versus its utility.

Setting the liquidity options aside and speaking more generally, we believe the most appropriate empirical estimate of liquidity given the ASE trading mechanism is the measure referring to the bid-ask quotes. Since the bid-ask spread exists as a natural consequence of the transaction costs, and is really formed as the hole in the central book of pending round lot orders, we argue we should decide about the liquidity status of the market examining the magnitude of the bid –ask spreads and the fist differences of them.

Despite our beliefs, we use three approaches in order to estimate the liquidity option prices. An issue arose during our efforts: the minimum allowed change in spot price in ASE changed on 1st January 2001 in order to take account of European Union currency, Euro(€).In doing so, the stock prices were converted from GRD to Euro, and the tick sizes were modified respectively*. We believe this change cannot leave the liquidity effect unaffected. Since the spot price of the stock now falls with a greater minimum allowed step, the negative returns will most possibly be broadened.

A solution could be to watch the downtick movements of the spot prices and assume the same would have occurred if the trading were made in Euro. We would then estimate the negative returns using the new tick size. As one can imagine, the liquidity effects would be more serious and the liquidity options more expensive.

The whole procedure is based on two questionable assumptions: a) the investors are indifferent to the magnitude of the tick size, and b) a change in the minimum price variations (tick size) does not affect the bid-ask spreads, a claim rejected by recent empirical studies [Harris, 1994]. Thus, we prefer not to modify our data but to use them as they are, in order to take an idea of the option prices they produce. Besides, every researcher who would like to make an empirical study for the pricing of a liquidity option starting today, would avoid this trouble right from the beginning, since he would select the most recent data available -data concerning 2001.

Another issue we should make clear is that the formula for pricing a liquidity option earlier described applies to the day before the staring day of the option, in particular, it applies to the eve of 1st November 2001, and as soon as the Stock exchange has closed. With the time passing, the time value of the liquidity option as well as its price declines. The formula should be modified for every trading day passing by, by taking off the forward start option just expired.

The estimated prices of the options, as well as the liquidity effects calculated, are not those we intuitively expected. Moreover, half of the option prices decline as a result to the percentage alteration (from 5% to 1,5% of the empirical distributions). Despite these remarks, we do not think we overestimated the utility of liquidity options. We attribute these results to our data set. The majority of empirical studies using transaction by transaction data for examining market variables and relations had at their disposal data for three to five years and hundreds of stocks.

We have the impression that since our data set was limited, perhaps we did not have the opportunity to observe fairly large transactions, large differences in the bid ask-spreads between to successive transactions, as well as fairly large time intervals without trading. In other words, we believe the market did not exhibit the full of its potential in the three-month period, thus our results may not reflect the liquidity effects outstanding in the real world.

Looking carefully at the prices of the options, we observe that the highest option prices are from ΑΕΓΕΚ. This should not mistakenly lead us to the conclusion that the liquidity options are to be addressed to listed firms of medium or low capitalization. Indeed, the opposite should be the case. If we also take into account the fact that ΑΕΓΕΚ has the smallest number of shares on free float while it displayed the largest liquidity effects, it is rational to say it revealed a larger percentage of its dynamics in the three-month period, in comparison with the other two firms. These thoughts strengthen further our belief that the shares of ALPHA ΤΡΑΠΕΖΑ and OTE did not reveal the most they can provide, in terms of negative returns associated with large sell orders, first differences in the bid-ask spread, and trade frequency.

* For stock closing prices between €3 and €60, the tick size now amounts to €0,02 or GRD6,815, while the previous tick had been GRD5 for closing prices between GRD1.000 and 19.999

Last but not least, we should mention that if we postulate that the liquidity effect is not linear in trade size as Blume, Easley and O'Hara argue [1994], but a convex function of it, the liquidity effects will rise more and more sharply as the trade size increases. In that case, liquidity options become an absolutely necessary instrument for liquidity provision in the capital markets.

The most significant assumption made in this paper is that the liquidity effect as well as the stock volatility does not change over time. In practice, this assumption is far from perfect. Current researchers try to find ways to include in a formula these parameters that do not seem to be constant but rather stochastic variables. As soon as a closed-form pricing formula for liquidity options is presented, we believe their great utility will be appreciated, and the legal frameworks will be revised in order to include such potential.

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