BANK OF GREECE

MEASURING LIQUIDITY IN THE GREEK GOVERNMENT SECURITIES MARKET

Thanasis N. Christodoulopoulos
Ioulia Grigoratou

Working Paper

No. 23 May 2005

MEASURING LIQUIDITY IN THE GREEK GOVERNMENT SECURITIES MARKET

Thanasis N. Christodoulopoulos
Bank of Greece, Financial Operations Department

Ioulia Grigoratou
Bank of Greece, Financial Operations Department

ABSTRACT

Liquidity in government securities markets, despite their importance to both private and public agents, has received much attention in the literature only recently due to the fact that high-frequency data from trading in those markets were previously unavailable. This paper attempts to measure liquidity in the Electronic Secondary Market for Securities, where Greek government securities are traded, by estimating six different liquidity measures from high-frequency data. The most appropriate measures for this specific market are derived from the analysis and comparison of the obtained estimates. By any of the measures examined, the ten-year benchmark bond is the most liquid security. The bid-ask spread emerges as a good measure of liquidity for the pre euro area entry period, but looses part of its importance in the post euro area entry period of our sample. An interesting finding is that, in the Electronic Secondary Market for Securities, liquidity is only weakly related to price volatility, probably due to the specific structure of the government securities market in Greece. Therefore, trading activity is also found to be a good proxy of liquidity in this specific market.

Keywords: Greek bond market, market microstructure, liquidity, order flow.
JEL classification: G10, D40, C40.

The authors wish to thank Heather Gibson from the Bank of Greece and Dimitrios Karampatos from the BIS for their helpful comments. We are also grateful to Nikos Alexopoulos for authorising data acquisition and to Stella Papadatou for making those data eventually available. We should also thank our colleague Sotiria Skaltsa for providing assistance with the market's institutional framework and Athanasios Dardaganis for readily offering us his IT expertise with data compilation. The views expressed are those of the authors and do not necessarily reflect the position of the Bank of Greece.

Correspondence:
Th. Christodoulopoulos,
Financial Operations Department,
Bank of Greece, 21 E. Venizelos Avenue,
GR-10250, Athens, Greece,
Tel. +302103202482
E-mail: tchristodoulopoulos@bankofgreece.gr

1. Introduction

Liquidity in government securities markets is of particular interest to both public and private agents. Central banks are interested because of the relevance of these markets to monetary policy and financial stability. Governments are interested in liquid and efficient markets primarily for reducing their borrowing costs. Private agents are concerned about liquidity as they use government securities for investment and hedging purposes, as collateral, and as a basis for pricing other fixed-income securities.

This is the first study dealing in a comprehensive and detailed way with liquidity in the Greek secondary market for government securities. The market has evolved as a two-tier market with an organised market being at the core and the over-the-counter market constituting the second tier. This structure has important consequences for certain aspects of liquidity that are analysed below, and also provides an explanation as to why our findings are differentiated to some degree from those of similar studies.

We examine liquidity over the period 1999-2003, by estimating six different measures for each of the three- five- ten- and twenty-year Greek government benchmark bonds. Those measures namely are: the trading volume, trading frequency, trade size, bid-ask spread, price impact coefficient and the on/off-the-run yield spread. As explained in Section 2, where the existing literature is briefly summarised, the level of liquidity is identified as the size of transaction costs faced by market participants. Consequently, the bid-ask spread captures, albeit only under certain conditions, accurately those costs. This also explains the popularity of this measure in the literature.

Market activity measures such as the trading volume and frequency are often employed as proxies for liquidity – active markets are thought to be liquid too – but a caveat that eventually may reduce their usefulness, is always present. The flaw inherent in the activity measures is the relation between price volatility and market activity where increased activity is often associated with higher volatility that impairs liquidity[1]. Liquid markets are markets with sufficient depth. The price impact coefficient and trade size are measures of market depth, though the latter can equally be thought as a measure of market activity too. The price impact coefficient estimates

the result on prices from net order flow, a concept that has recently received much attention in the relevant literature.

Beyond the aforementioned five liquidity measures the categorisation of which is outlined above, the on/off-the-run yield spread is also examined. This additional liquidity measure can be classified neither as an activity nor as a market depth or transaction costs measure. It measures in a rather direct way the specific value placed by traders on more liquid bond issues. Certain prerequisites are necessary in order for the on/off-the-run yield spread to convey important information on market liquidity. Unfortunately, those prerequisites – e.g. an active repo market and regular/frequent issuances – are not easily met.

We first analyse the estimations of the various measures obtained by using descriptive statistics which allow us to reach important conclusions about the level of liquidity in the Greek market over the past few years. Then, with simple correlation analysis, we explore the relation across the different measures and price volatility. Principal component analysis is also employed in order to compare the different liquidity measures and verify their theoretical classification. This comparison will enable us to get a fairly good idea of the most important ones for the Greek market.

Naturally, our findings can be compared with the results of similar studies for government securities markets in other countries. Of course, our measurement results are, by nature, static and cannot be considered definite since the Greek market has been, over the period under consideration, constantly evolving and will probably continue to do so in the near future. Also, the market has functioned under important micro- and macro-developments that merit, and indeed have received, particular attention in the analysis undertaken.

The remainder of this paper is organised as follows. Section 2 reviews the literature on the notion of liquidity and the ways proposed to measure it. Section 3 contains a presentation of the Greek government securities market microstructure that sets the framework in which the different liquidity measures are considered. The high-frequency data available for analysis as well as the sample period are described in section 4. Sections 5 and 6 contain the estimation results obtained for the various liquidity measures together with a comparison of those measures in an attempt to identify the most appropriate ones among them. A comparison of our findings with

[1] For instance, it is common to observe wider bid-ask spreads during periods characterised by increased volatility.

those of similar studies for other markets is attempted in section 7. Finally, section 8 concludes the paper.

2. Liquidity: notion and measures

Liquidity directly affects price formation. Amihud and Mendelson (1986, 1989) were the first to model and test this relationship with data from the stock market. Their results indicate that the return on assets is an increasing function of their illiquidity as investors require a premium for bearing higher transaction costs. With respect to fixed-income markets, Amihud and Mendelson (1991) provide evidence on the return-liquidity relationship from the US treasuries market. Their findings were confirmed by Warga (1992), Daves and Erhardt (1993), Kamara (1994) and more recently by Strebulaev (2001). Goldreich, Hanke and Nath (2003) show that the impact of liquidity on current prices depends on the expected future liquidity over the security's remaining lifetime rather than on current liquidity.

Since liquidity has value, its price can be inferred from the price difference between a more and a less liquid security with similar cash-flow characteristics and identical credit risk. In the US government securities market, the yield spread between the on-the-run and the first off-the-run security[2] is often used as a measure of liquidity [Goldreich, Hanke and Nath (2003), Fleming (2003), Furfine and Remolona (2002), Duffie (1996)]. The fact that the calculation of this spread does not require high-frequency data, as other liquidity measures do, constitutes a considerable computational advantage but its usefulness as a liquidity measure depends much upon the characteristics of this particular market[3]. In Section 5, we provide estimates of the liquidity spread in the Greek government securities market though we encounter problems in their interpretation. This, however, does not prevent us from including the liquidity spread in the comparative analysis of the various measures since, in this type of analysis, it is movements rather than absolute values that are considered.

[2] The on-the-run security is the most recently issued security for a given maturity. This security is also characterised as the benchmark security for this maturity. The benchmark status is waived and this same security becomes the first off-the-run security once a new security for the given maturity is issued.

[3] Such as the security issuance cycle or the importance of the repo market and the "specialness" of specific securities in this market.

A perfectly liquid market is defined as one in which trades can be executed with no cost [O'Hara (1995)]. The level of liquidity is, thus, defined by the size of transaction costs. The market microstructure literature has focused primarily on the bid-ask price spread as a measure of transaction costs and market efficiency. Grossman and Miller (1988) discuss, among others, the shortcomings of the bid-ask spread as a measure of transaction costs while Hasbrouck (1993) proposes some improved measures based on the decomposition of transaction price time-series into a stationary and a random-walk component. Beyond the quoted bid-ask spread, which we too analyse in Section 5, several variants of it (such as the relative or the effective spread) have been used in the literature[4] depending on the particular market structure considered and data availability.

Furthermore, as described in Glosten and Harris (1988), Stoll (1989) and Madhavan, Richardson and Roomans (1997), the spread can be decomposed into an asymmetric information component and a fixed cost component. Since only the fixed cost component[5] represents transaction costs, the bid-ask spread constitutes a good proxy of liquidity only if adverse selection is absent when market participants trade. One should *a priori* expect information asymmetries to be rather limited in a wholesale government securities market which is transparent and where only well-informed institutional investors participate. As we shall see in Section 3 where we discuss market structure, the Electronic Secondary Market for Securities in Greece possesses those qualities.

The notion of market depth is closely related to liquidity. Market depth is usually captured by the quote size (= the proposed quantity of securities to buy/sell) at the posted bid-ask prices. In a deep market, the probability of finding matching orders for large trades with minimal price impact is high. A liquid market is, therefore, perceived as a market being deep enough in this sense. The size of trades is an *ex post* measure of market depth and, in some respect, superior to the quote size since the latter may not always reveal the full size for which there is willingness to trade at a given price. The size of trades is not only a proxy for market depth but also for trading activity as explained below.

[4] See, for instance, Cao, Field and Hanka (2004), Meneu and Pardo (2004) and Favero, Pagano and von Thadden (2004).

[5] It includes costs such as those for handling the order, financing the inventory, maintaining market membership and providing for a profit margin.

Alternatively, market depth is measured as the inverse of the price impact from a trade. In the context of a model incorporating asymmetric information across traders, Kyle (1985) introduced the notion of the price impact coefficient which accounts for the adjustment in prices to reflect the information content of trades. The latter is proxied by the order imbalance, i.e. the buyer-initiated minus the seller-initiated trades over a specific time interval. Estimates of the price impact coefficient for the US treasury securities market are provided in Fleming (2003) whereas D'Souza, Gaa and Yang (2003) provide similar estimates for the Canadian market. In Section 5, we provide estimates of the price impact coefficient for the Greek government securities market.

The trading activity for a given time interval, e.g. daily, is measured by the realised trading volume and/or the realised number of trades (trading frequency). Since trading volume can be decomposed into the number of trades and the size of trades [Chan and Fong (2000)], the size of trades can be classified as a third measure of trading activity. The relationship, however, between trading activity and liquidity is not clear. On the one hand, intense trading activity is considered a characteristic of a liquid and efficient market while, on the other hand, experience has shown that volatility in financial markets is often accompanied by episodes of illiquidity although trading activity remains intense. Consequently, the trading activity-volatility relation merits, and indeed has received, particular attention in the literature.

There are a significant number of empirical studies[6] documenting a positive volume-volatility relationship based on evidence mainly from the equity, futures and foreign exchange markets. In Karpoff (1987), there is a review of early theoretical and empirical research. Jones, Kaul and Lipson (1994) examine the trading volume, trading frequency and the average trade size as determinants of volatility and find that trading frequency appears to provide virtually all the explanation for the volatility-volume relation with trade size offering no additional explanatory power. Chan and Fong (2000) examine the role of trading frequency, order imbalance and size of trades (by classifying trades into different trade size categories) on price volatility. They

[6] Theoretical models on the volume-volatility relation fall into three classes of models: 1) competitive [Shalen (1993), Harris and Raviv (1993), Grundy and McNichols (1989), among others] where agents differ in their beliefs and respond differently to the arrival of (public) information; 2) strategic [Holden and Subrahmanyam (1992), Admati and Pfeiderer (1988), Kyle (1985), among others] that incorporate asymmetric information and informed investors submit trades on the basis of their private information; 3) models built on the mixture of distribution hypothesis [Harris (1987), Tauchen and Pitts (1983),

reconfirm the results of Jones *et al.* as regards the significance of the positive relation between price volatility and trading frequency (and volume to a lesser extend) but they also find that order imbalance explains a substantial portion of price movements; after controlling for this effect, the trading frequency-volatility relation becomes much weaker. Furthermore, the results of Chan and Fong confirm the significance of the size of trades beyond that of the number of trades in the volume-volatility relation[7].

An interesting result of Chan and Fong (2000) is that large trades appear to be less significant in interpreting price volatility. By studying the volume-volatility relationship in the U.S. treasury notes market, Huang, Cai and Wang (2002) find that volatility is positively correlated with trading frequency, but negatively correlated with trade size. Downing and Zhang (2004), by examining evidence from the municipal bond market[8], find a positive relation between the number of trades and price volatility but a negative relation between the average trade size and volatility, even after controlling for the trading frequency of a particular bond. The interpretation put forward is that the larger the trade size, the more likely the trade is to take place between well-informed traders with minimum impact on prices. Meneu and Pardo (2004) reach a similar conclusion but in a different context. Below we analyse trading activity in the Greek government securities market and explore its relation with price volatility.

3. The Greek government securities market

The size of the government debt and the liberalisation of the financial sector led to the development of a substantial secondary Greek government securities market in the mid-90s. This market was established on an over-the-counter (OTC) basis. The limited transparency, liquidity, efficiency and flexibility inherent in this OTC market was reflected in the high bid-ask spreads which occasionally exceeded 500 basis

among others] -information arrivals being the mixture variable- which are primarily statistical models as opposed to equilibrium models of economic behaviour.

[7] The results obtained, nevertheless, are differentiated to a certain degree according to the market's microstructure, i.e. upon whether individual stock trading data come from the NYSE or Nasdaq.

[8] A market that can be characterised as illiquid compared to the stock or the foreign exchange market. It is an over-the-counter market, with limited transparency, where the majority of market participants are large institutional investors.

points (bps) and highlighted the need to launch an organised[9] trading venue, which would facilitate trading and contribute to the efficient pricing of Greek government securities. Responding to these needs, HDAT (The Electronic Secondary Securities Market) was initially established in 1997[10] and started operating in May 1998.

The new market's framework distinguishes between two categories of market participants: primary dealers who are required to fulfil the task of supporting the market with their market-making activity and secondary dealers. Primary dealers are granted the exclusive right of participating in treasury auctions. HDAT's trading system is electronic, quote-driven, and primary dealers are obliged to provide firm quotes and achieve a minimum of activity, on a yearly basis, in terms of transactions volume. As market participants admit, HDAT soon became a successful trading venue characterised by efficient price formation.

The Bank of Greece acts both as an operator and a host to HDAT and the Governor of the Bank appoints the Supervisory Committee of HDAT, which consists of 7 members. The Committee consists of two representatives of the Bank of Greece, three representatives of the primary dealers and two of the secondary dealers. The Committee also performs a supervisory role in relation to the Hellenic Republic's securities auctions, where an eighth member from the Ministry of Finance also participates.

As a rule, all dematerialized government debt is listed and traded on HDAT. Government debt securities in all local institutional portfolios are required by law to be marked to market on a daily basis using market prices, as the latter appear in HDAT's daily price bulletin. This considerably increases the significance of price formation in HDAT.

HDAT is linked electronically and in real-time with information systems such as Telerate, Reuters and Bloomberg. This way, trading information is widely diffused, promoting transparency. HDAT was designed, from the outset, to be a wholesale market reserved for institutional investors. Being a quote-driven market, firm two-way anonymous quotes are always available from the market makers. Market participants can see the best quotes at any time but anonymity remains until a trade is crossed. At that stage, the identity of the counterparties (the buyer and the seller) is revealed, albeit, only between them. A minimum number of five quotes per issue is

[9] As defined in the Investment Services Directive 93/22/EEC.
[10] Law 2515/97

set by regulation, and members can see all active quotes posted in the system. Participants enter buy or sell orders when they see a price at which they wish to trade. By specifying the quantity for which they intend to transact, they are also allowed to indicate a price limit up to which they commit themselves if the desired quantity is higher than the one available at the best price. Orders are matched automatically by the system and the transactions are finalized by DVP (Delivery versus Payment). Simultaneous accounting entries (credit/debit) take place as regards the securities-leg and the cash-leg of any transaction, a procedure that substantially reduces systemic risk in clearing and settlement. All transactions are settled with a value date of T+3.

The price of a security published in the HDAT Bulletin is the best bid price drawn for this security at a random moment during the day, usually towards the end of the trading session. HDAT's operating hours are from 10 a.m. to 5 p.m., the first 15 minutes being a preparatory period during which market makers prepare their quotes. During this preparatory period, each market maker has access only to his own quotes which are not revealed to the rest of market.

Quotation of prices and quantities in HDAT are subject to two main regulatory restrictions: A maximum bid-ask price spread and a minimum quote size. The maximum bid-ask spread was initially set at 50 bps, a level which, at the time, was considered satisfactorily low compared to the levels prevailing in the OTC market (especially when taking into account the fact that the spread widened to 555 bps during the 1997 South-East Asia financial crisis). The achievement of a relatively low spread was sufficiently tested during the next period of turmoil which took place while HDAT was in operation, the 1998 Russian crisis, when the bid-ask spread inevitably widened but only to a maximum of 90 basis points.

Since May 2001, the maximum bid-ask spread varies in accordance with the residual maturity of the security and reaches 15 bps for maturities exceeding 11 years. The maximum bid-ask spread for maturities up to 5 years is 7 bps while for the maturities from 5 to 11 years is 10 bps. The uniform, i.e. regardless of residual maturity, maximum spread imposed initially was gradually brought down considerably. It was reduced to 25 bps in December 1999 and subsequently to 20 bps in June 2000, to 15 bps in October 2000 and to 10 bps in January 2001, when the country joined EMU.

Currently, the minimum quote size represents an offer for 10 lots, while any order above the minimum should be a multiple of 1 lot (1 lot = 500,000 euros). When

HDAT started its operations, 1 lot was equivalent to one hundred million Greek Drachmas (about 293,000 euros) and the minimum quote size was 5 lots. Subsequently, the minimum quote size was first doubled to 10 lots and from 1 December 1999 was increased to 20 lots (or a total face value of approximately 5,869,406 euros). From 2 January 2001, the value was adjusted to the current minimum of 5 million euros.

An order to buy or sell a security includes the price, the size and the time stamp. Price is the first parameter used to determine the best offer. Subsequently, when there are multiple offers at the same price, priority is given to the largest size. Among offers of the same price and size, the best is considered to be the one that has been first posted in the system.

HDAT started to operate with 13 primary dealers and 23 secondary dealers, thus a total of 36 market participants, among which 21 were Greek credit and financial institutions and 15 were local branches of foreign banks. The total number of market participants has remained roughly constant over the years. Its composition, nevertheless, has been considerably modified. The number of HDAT members and their classification into primary and secondary dealers is set at the beginning of each year jointly by the Finance Minister and the Governor of the Bank of Greece. During 2004, 20 financial institutions were acting as primary dealers[11], among which, 5 were Greek credit institutions and the remaining 15 are foreign institutions, few of which have branches in Greece. The securities that each primary dealer is obliged to quote for are also determined at the beginning of each year and include all the benchmark issues as well as a number of additional securities attributed to each dealer.

Those market participants who are not located in Greece are granted remote access to trading and for this purpose have at their disposal HDAT screens in their location. Remote access was not an option when the market was launched and it was only introduced in mid-2000. Undoubtedly, this development had a significant positive effect on market's liquidity and depth.

[11] The Primary Dealers for 2004 are: Alpha Bank, BNP Paribas, Citigroup Global Markets, Credit Suisse First Boston (Europe) Ltd, Deutsche Bank, EFG Eurobank Ergasias, National Bank of Greece, Commercial Bank of Greece, Goldman Sachs International, HSBC Bank, ING Bank, JP Morgan Securities, Lehman Brothers Intl. Europe, Merrill Lynch International, Morgan Stanley & Co Intl Ltd, Nomura Intl, San Paolo–IMI, Unicredit Banca Mobiliare S.p.a and the Bank of Piraeus.

4. Data and sample period description

For the purpose of the study in hand, high-frequency data were obtained from HDAT. These data concern time-series of quotes and transactions data for the three, five, ten and twenty-year on-the-run Greek government securities[12]. The transactions data per individual security, with the time of each transaction indicated to the second, include the transaction price, the size as well as an indication of whether a trade is a buyer or a seller-initiated one[13]. Consequently, the liquidity measures of trading volume, trading frequency and trading size can be calculated directly from those data. The set of transactions data also serve as a basis to generate the time-series of the variables required in order to obtain the estimates of the price impact coefficient.

As described previously, the setup of HDAT's trading platform does not allow for negotiation between interested dealers over either price or quantities. All trades take place exclusively at the prices and sizes posted in the system. As a result, quoted bid-ask spreads provide a very accurate indication of the spreads market participants face. Also, contrary to what is encountered in the markets studied by Fleming (2003) or D'Souza, Gaa and Yang (2003), trade "workup" – i.e. the possibility of increasing the trade size after a trade is crossed – cannot take place.

The time-series of quotes per individual security include the following: the bid and ask prices, the respective sizes and the time-stamp. HDAT does not keep historical records of the best quotes appearing in the system. This constitutes a drawback in the analysis since it limits our ability to study the bid-ask spread in a proper way. Instead, HDAT keeps historical records of all the quotes provided by each primary dealer individually. We opted to use the time-series of quotes provided by a specific primary dealer[14] as a proxy of the best quotes appearing in the system in order to study the bid-ask spread.

Another particularity observed in the quotes provided by HDAT is that the reported sizes exhibit a remarkable stability close to the minimum size imposed by regulation. This holds in general true irrespective of the source, i.e. the primary

[12] Throughout this study we use the terms "on-the-run" and "benchmark" interchangeably.
[13] In total, we study a pool of 43,083 trades for the ten-year benchmark bond, 26,761 trades for the twenty-year benchmark bond, 24,433 and 9,410 trades for the five and three-year benchmark bonds respectively.
[14] The National Bank of Greece (NBG). NBG is one of the most active primary dealers according to the ranking list regularly published by HDAT. We study a pool of 89,767 NBG quotes for the ten-year benchmark bond, 100,086 quotes for the twenty-year benchmark bond, 62,605 and 34,934 quotes for the five and three-year benchmark bonds respectively.

dealer, from which the quotes come from. The latter led us to conclude that the information content of the respective data set is negligible and we, therefore, abstained from studying the quote size as a measure of market's liquidity. The size of a single transaction, nevertheless, can be higher than the quoted size since a number of market makers simultaneously may post, for a given price, the minimum_size. Orders of a size other than the minimum can then be fulfilled by matching successively the different postings, at the same price, appearing in the system.

This paper focuses on the liquidity of the benchmark bonds, disregarding bills. The trading of Greek government bills in HDAT is virtually non-existent due to the fact that those securities are mainly held by retail investors. Bills, due to their nature, are usually held by investors until maturity. Benchmark bonds comprise only four issues out of a total of roughly seventy issues outstanding. Chart 1 shows the evolution of the total transactions volume in HDAT as well as of the transactions volume in the four benchmark bonds over the period under consideration. On average, almost half of the volume realised in HDAT is attributed to the benchmark securities. The total transactions volume in Greek government securities, including transactions in the OTC market, is significantly higher than the volume realised in HDAT. Though details of trading in the OTC market are not available, the transactions volume is registered by the securities depository. It appears that the total transactions volume in Greek government securities stands at four to six times the trading volume realised in HDAT.

At this point, certain remarks are necessary. The Greek market functions as a two-tier system with HDAT being the core. The launching of HDAT did not reduce the significance, in volume terms, of the OTC market. On the contrary, the realised volume in the latter is several times the trading volume of the former. HDAT, however, plays a predominant role in price formation. Supplementary evidence of this is given by the fact that local brokerage firms[15] in government securities were gradually driven out of business. Also, large foreign institutional investors were attracted over time to participate as primary dealers, broadening significantly the investor base. Experience shows that transactions in the OTC market are carried out at

[15] The main role of these firms is to perform a price discovery function.

prices which are very close to the ones indicated in HDAT and that those transactions are mainly large ones[16].

This market structure has important consequences for the quality and interpretation of the estimates of the different liquidity measures derived in section 5. For instance, the impact of asymmetric information on the bid-ask spread is expected to be limited; alternatively, there should be no price volatility induced by large trades. In this paper we attempt to measure liquidity by analysing high-frequency data capturing only a portion, albeit the most informative, of trading activity in Greek government securities. As a result, the measures of trading activity – particularly that based on trading volume – underestimate total activity[17]. On the other hand, the bid-ask spread should capture quite accurately transaction costs[18] and, since measured volatility is isolated from the possible impact of large trades on prices, the price impact coefficient measures market depth rather accurately. Finally, the trade size *a priori* emerges as a weak measure of both total trading activity and market depth.

Our sample period ranges from 29 January 1999 to 11 November 2003 for all benchmark securities aside from the twenty-year one for which the sample begins on 12 January 2000 when twenty-year bonds were first launched. During the period under examination, important events occurred, even if major financial crises that could severely stress the market were absent. The participation of Greece, from January 1 2001, in EMU was a major event with important consequences for the evolution of the bond market and the Greek economy in general. Related to it were the successive upgrades of the country's credit rating by the major international rating agencies. S&P upgraded the rating of the Hellenic Republic by one notch on 13 March 2001 (from A- to A) and FITCH on 20 June of the same year (also from A- to A). Moody's upgraded the rating of the Hellenic Republic by one notch on 4 November 2002 from A2 to A1 (A1 corresponds to an A+ rating in the scale of S&P and FITCH). Furthermore, S&P (on June 10) and FITCH (on October 20) upgraded the country's profile in the course of 2003 to the level already assigned by Moody's in November of the previous year. In the light of this we should consider euro area participation as a structural break in our data series and, in fact, we do so in all aspects of our analysis. The September 11 event is another major event within our sample

[16] Compared to the average trade size estimated below in section 5.
[17] It does, however, capture the evolution of activity and the underlying trends.

period. Chart 2 illustrates these developments and plots the ten-year benchmark bond yield and the European Central Bank's main refinancing operations rate. The post euro area entry era, characterised by successive rate cuts, also constituted a very benign environment for bonds.

Chart 3 depicts the price volatility of the ten-year benchmark bond, calculated weekly as the standard deviation of trade-by-trade price changes using transaction prices. From the chart it is apparent that, ignoring the peaks corresponding to the issuance of a new benchmark where the increased volatility reflects merely the one-off price adjustment and can thus be considered artificial[19], there were no major volatility episodes in the post euro area entry period. One possible exception is the twelve-week period ending on 7 December 2001, following the September 11, during which progressively higher peaks in volatility are observed. This particular period is characterised by a mixture of increased trading activity[20] as well as spikes in volatility. In the pre euro area entry period, several volatility peaks appear in the course of 1999. Presumably, the uncertainty surrounding the path of the economy's convergence towards the Maastricht criteria as well as the fact that HDAT was still a young market, as it was only its second year of operation, played a role.

The measure of the yield spread between on-the-run and off-the-run bond issues is calculated from a data set obtained from Bloomberg. This set comprises end of day yields for each individual security. The sample period spans 12 May 2000 to 11 November 2003 for the ten and five-year maturities including a total of five and four bond issues respectively. For the three-year maturity, the sample begins on 11 February 2000 and ends on 11 November 2003 including four issues, while for the twenty-year maturity the sample begins on 24 April 2002 and ends on the same date as previously, including two issues only.

The high-frequency data obtained from HDAT have been processed and, where necessary, aggregated. All tables in section 5 showing descriptive statistics for the various liquidity measures are based on an analysis conducted at the daily level while the charts presented are based on an analysis conducted at the weekly level. The

[18] One should not, nevertheless, overlook the remark on the unavailability of data on best quotes made previously.

[19] Indeed, we have excluded the respective observations from the final data set on which we based our estimations presented in section 5. The one-off price adjustment that occurs when passing from the old to the new benchmark bond is due to the difference in maturity between the two bonds, i.e. the time span between the two consecutive issuances, without any actual change in yields.

[20] As shown in the analysis of the individual liquidity measures in section 5.

regressions related to the estimation of the price impact coefficient are performed both at a disaggregated (trade-by-trade) level and at an aggregated (hourly and daily) level. The sample used for the hourly changes in the regressed variables begins on 1 November 2002 because the trading frequency achieved in HDAT allows for this kind of analysis only from that date onwards.

Overall, it must be stressed that the period under examination is characterised by intense and constant evolution of the bond market as well as by considerable changes in the economy as a whole. The newly-launched trading venue gained credibility gradually and became well established among market participants. The Treasury progressively made issuances more regular; it introduced the pre-announcement of the quarterly borrowing schedule and extended the longer-end of the curve by adding the twenty-year maturity. The economy, after following a certain convergence path, met the Maastricht Treaty criteria and joined the euro area. Subsequently, Greek government debt was integrated into the euro area debt and, in fact, was treated by investors as an attractive alternative to pick up additional returns because of the relatively higher country risk.

5. Empirical results

5.1. Trading Volume

Table 1 shows trading volume descriptive statistics for each on-the-run issue of Greek government bonds. The ten-year bond appears to be the most actively traded security in HDAT with a mean (median) daily volume of EUR 208.3 million (EUR 120 million). The three-year bond is shown to be the least active with a mean (median) daily volume of EUR 67.8 million (EUR 35 million). The large dispersion around the mean and the important divergence between the mean and the median values (the median is considerably lower than the mean) suggest a market under constant evolution. By breaking down the sample into the pre euro area entry and the post euro area entry period (Table 1A) the results illustrate the big increase in trading volume in recent years. The dispersion around the mean remains large but the distance between the mean and median values is reduced. The ten-year bond remains, in terms of volume, the most actively traded security with a daily average volume of 313 million euros. The second most actively traded security is the five-year bond with a

daily average of 193 million euros. Comparing the relative figures, we observe an eightfold increase of the average daily volume realised in the ten-year bond between the two periods[21].

Average daily trading volume by week for the five and the ten-year on-the-run securities are shown in Chart 4. The significant increase in the post euro area entry period is conspicuous. In general, the economic environment characterised by a cycle of successive rate cuts – of a total of 250 bps – was very favourable to fixed income instruments. Furthermore, the upgrading of the credit rating of the Hellenic Republic by Moody's in November 2002 seems to have brought about a considerable increase in trading volume – especially pronounced for the ten-year bond. The upgrade by Moody's is an event of particular importance because, historically, this rating agency has always opened rounds of the upgrades with other agencies following suit. Indeed, both S&P and FITCH upgraded the country's rating in the fall of 2003, an action that apparently reinforced trading volume. Chart 4 also suggests that the upgrading of the country's credit rating (by S&P and FITCH) in the course of 2001 had a positive effect on trading activity but the large increase observed in the fall of the same year should also be attributed to safe-haven flows into bonds following the September 11 event, accompanied by the successive rate cuts on behalf of the ECB.

5.2. Trading Frequency

Daily trading frequency descriptive statistics for the on-the-run issues are reported in Table 2. The table shows that the most actively-traded bond in terms of volume (the ten-year bond) is also the most actively- traded in terms of frequency (trades per day). The second most actively-traded bond appears to be the twenty-year bond while the five-year bond ranks third. The ten-year bond exhibits a mean (median) of 37.6 (24) trades per day. The three-year bond is again the least actively traded security with a mean (median) of just 11.1 (7) trades per day. The large dispersion around the mean and the large distance between the mean and median values indicate again a market undergoing evolution. By breaking the sample into the pre euro area entry and the post euro area entry periods (Table 2A), the results reveal

[21] Volume is positively correlated across the different maturity bonds with the five and ten-year securities the most correlated (with a correlation coefficient of 0.64).

an approximately sixfold increase in trading frequency of the ten-year bond in the period after 1 January 2001[22].

In Chart 5, we present average daily trading frequency by week for the ten- and five-year bonds. The patterns are very similar to those detected when analysing trading volume (Chart 4). Again, the chart makes the significant increase of trading frequency in recent years plainly evident.

5.3. Trade Sizes

Table 3 reports descriptive statistics for average daily trade sizes for the four benchmark bonds. The mean and median trade size appear very close (both around EUR 5 million). In addition, the dispersion around the mean is relatively small. Contrary to what we detected regarding the previous two measures, average trade size has not changed much over the period under examination. The results obtained by breaking down the sample into the pre euro area entry and post euro area entry period (Table 3A) are slightly different from the ones reported for the entire sample but similar conclusions can be drawn. These findings are partly generated by the lower limit on quoted size imposed by the regulatory framework and the response of market makers usually to post quotes of minimum size only[23].

The mean trade size is inversely related to the maturity of the benchmark. Considering the increased interest rate risk per euro of face value associated with a position in a higher-duration security, this finding is justified.

Chart 6 plots average trade sizes by week for the five- and ten-year benchmark bonds[24]. The observed jump in trade size towards the end of 1999 reflects the doubling of the minimum size[25] for which market makers were obliged to quote. It was slightly revised again in January 2001 to 5 million euros, the size that continues to apply today. Nevertheless, the previously described patterns supportive of increasing trading activity can be easily verified from Chart 6 in terms of trade sizes too.

[22] Trading frequency is positively correlated across securities, with the five and ten-year bonds having the highest correlation coefficient of 0.65.
[23] Trade sizes tend to be positively correlated across securities, with the five- and ten-year bonds the most correlated (correlation coefficient = 0.42).
[24] It should be clarified that in Chart 6, the average weekly trade size falls below the minimum size quite often especially during the pre euro area entry period due to sparse trading where on some days there was no trade at all in the respective securities.

5.4. On-the-Run / Off-the-Run Yield Spreads

Table 4 provides descriptive statistics for the daily on-the-run/off-the-run yield spreads. The spread is calculated as the end-of-day yield of the first off-the-run security minus the end-of-day yield of the on-the-run security. Thus positive spreads indicate that on-the-run securities are trading at a lower yield, or higher price, than off-the-run securities because their benchmark status renders them more liquid and investors are prepared to pay a premium in order to trade in them.

Contrary to what is normally the case[26], the table shows that average spreads are negative, with the ten-year bond having the lowest mean (median) standing at -5.49 bps (-5.50 bps). This is probably explained by the relatively long time that elapses between two consecutive issuances of securities with the same initial maturity (the Greek Treasury has issued, so far, new benchmark ten-year bonds only once a year and even less frequently other maturities), a fact that differentiates the cash flows of the securities. In addition, over most of the sample period, a strongly upward-sloping yield curve has prevailed. The usefulness of the on-the-run/off-the-run yield spread analysis is in our case significantly reduced since infrequent issuances represent a factor that further hinders efforts to establish a link between the observed spread and market's liquidity[27].

Average daily on-the-run/off-the-run bond yield spreads by week for the five- and ten-year securities are plotted in Chart 7. There, it can be observed that the issuance of a new benchmark reduces the spread while the September 11 event caused a widening of this spread. A positive average spread appears for most of 2000. This result is merely due to the fact that the yield curve was inverted at the time because Greek rates were expected to converge eventually to the (lower) euro area rates.

5.5. Bid-Ask Spreads

Table 5 reports descriptive statistics for the average daily bid-ask spreads for the on-the-run securities. Consistent with market quoting conventions, bid-ask spreads are reported in basis points[28] (par prices are at 100). Considering the entire sample period, mean bid-ask spreads do not differ much across securities. Normally, longer

[25] From 2.9 to 5.8 million euros.
[26] Goldreich, Hanke and Nath (2003), Fleming (2003), Furfine and Remolona (2002), Duffie (1996).
[27] The absence of a significant repo market also plays a role. The repo market generates the "specialness" of (benchmark) securities, a fact that causes those securities to be traded with a premium reflecting their increased liquidity.

maturity securities tend to be more volatile (in price terms) and thus to have wider bid-ask spreads. According to the results obtained (Table 5A), this happens only during the post euro area entry period, when the twenty-year bond has the highest mean (median) daily bid-ask spread of 13.53 bps (14.46 bps) while the five-year bond the lowest of 6.97 bps (6.90 bps). The three-year benchmark bond is found to have a slightly higher average bid-ask spread of 7.09 bps[29]. The significant size of the standard deviation figures in Table 5A reveal that the relative limits imposed by regulation were not binding for the majority of quotations.

Average daily bid-ask spreads by week for the five- and ten-year securities are plotted in Chart 8. The gradual reduction of the imposed maximum bid-ask spread from 50 to 10 basis points during the pre euro area entry period is clearly depicted. Only the September 11 event caused a temporary widening of the spread beyond the maximum level imposed. The market regulatory authority permitted this development dictated by the exceptional circumstances prevailing at the time. It was, nevertheless, very short-lived and did not surpass 15 basis points[30].

5.6. Price Impact Coefficients

The price impact coefficient relates net trading activity to price changes. Net trading activity is captured here by two distinct measures: the daily net trading volume and the daily net number of trades. Net trading volume is defined as the buyer-initiated less the seller-initiated trading volume. Tables 6 and 6A contain the related descriptive statistics. The negative mean value indicates the predominance of selling activity that can be explained by the role of primary dealers who first acquire securities in the auctions conducted by the treasury and then act as net sellers in the secondary market. The net number of trades equals the number of buyer-initiated less the seller-initiated trades. Tables 7 and 7A show the related descriptive statistics. The observed minus sign of the mean net number of trades reveals again a predominance of selling activity.

Chart 9 provides preliminary evidence of the relationship between daily price changes and net trading activity, the latter depicted by the net number of trades. The

[28] Calculated as the ask price minus the bid price. Transaction costs are one-half of this spread.
[29] Bid-ask spreads tend to be positively correlated across securities, with the five- and ten-year bonds having the highest correlation coefficient of 0.32.
[30] In the period from 12 to 14/9/2001.

chart reveals that the direction of the relationship is positive, i.e. buyer-initiated (seller-initiated) trades are associated with rising (falling) prices, as expected.

Tables 8-12 show the regression results for the ten-year benchmark security. The dependent variable is price changes while the net trading volume, net number of trades, proportion of buyer-initiated trades, number of buyer-initiated trades and the number of seller-initiated trades are the explanatory variables considered individually (regressions 1-3 in each table) or in some combination (regressions 4-5 in each table). Tables 8-9 contain the regression results after breaking down the sample into the pre euro area entry and post euro area entry period and using aggregated daily data. Tables 10-11 present the regression results without any form of aggregation, i.e. the variables are measured on a trade-by-trade basis, after breaking down of the sample into the pre euro area entry and post euro area entry period. Finally, Table 12 shows the results obtained from the regression of one-hour price changes on the above-mentioned explanatory variables measured over the same interval. The obtained results vary, to certain extent, between periods and depend on the level of aggregation. Considering changes at a daily level, we probably overlook important information contained in intra-day trading. On the other hand, examining changes on a trade-by-trade basis, the analysis may be blurred by noise inherent in high-frequency data, e.g. the asynchronous reaction of traders to information arrivals. We shall, therefore, focus more on the results obtained from considering hourly changes.

The estimated coefficients are statistically significant in all forms of equations shown. The adjusted R^2s in the pre euro area entry and the post euro area entry sample period (results in Tables 8-9 and Tables 10-11) indicate that the explanatory power of order imbalance is reduced during the post euro area entry period The result is more pronounced when considering daily changes (Tables 8-9). The impact in the pre euro area entry period, for instance, of the net number of trades accounts for 29 percent of the variation in price changes whereas this explanatory power is reduced to 11 percent in the post euro area entry period. When considering hourly changes (regression 1 in Table 12), the net number of trades accounts for 26 percent of the variation in price changes. Among the regressions where the three independent variables are taken individually, that of the net number of trades has the highest explanatory power. The net number of trades, thus, emerges as the most important variable in explaining market depth.

The price impact coefficients obtained from considering one-hour changes are shown in Table 12. One trade net brings about a 0.85 bps change in price, or alternatively, about twelve trades net move the price of the ten-year security by one basis point. The net trading volume coefficient implies that one trading lot net (or five-hundred million euros of face value) induces a 0.0014 bps change in the price of the ten-year benchmark security[31]. Also, the coefficient of the proportion of buyer-initiated trades is positive and highly significant (regression 3), albeit with lower explanatory power.

In regression 4, where the net number of trades and the net trading volume are combined to explain price changes, the coefficient of the net number of trades is positive and twice as large as in regression 1. The coefficient of the net trading volume is, however, negative[32]. This result is explained by the way trade size is associated with price volatility. There is a considerable literature [Jones, Kaul and Lipson (1994), Chan and Fong (2000), Huang, Cai and Wang (2002), Downing and Zhang (2004)] documenting an insignificant – or even negative – relationship between trade size and volatility. In fact, we too found, by separating trades into small and large ones, that larger trade sizes are associated with smaller price changes. Similar conclusions are reached by Fleming (2003) when he considers the effect on price changes of both the net number of trades and net trading volume.

In regression 5, where the net number of buyer and seller-initiated trades are combined in explaining price changes, the estimated coefficients have the expected sign and are highly significant. The magnitude of the coefficient of seller-initiated trades is larger, suggesting that selling activity has a greater effect on prices than buying activity. In that respect, sell orders may be seen as conveying more information than buy orders. Related is our remark, made previously when commenting the results in Tables 6 and 6A, concerning the participation of primary dealers in the Greek treasury auctions and subsequently their activity in the secondary market.

By comparing the price impact coefficients presented in Tables 8-9 as well as in Tables 10-11, we observe a remarkable improvement of market depth between the pre euro area entry and the post euro area entry period. For instance, the price impact

[31] Both coefficients have the right sign.
[32] Its value is slightly smaller than the value of the coefficient in regression 2 and it is considerably less significant.

coefficient of the net number of trades implies that the market became three to five times more liquid in the post euro area entry period.

The above results are quite similar to the results obtained from the regressions for the other on-the-run securities, though the results obtained for the three-year bond are generally less statistically significant.

6. Comparison of liquidity measures

In this section, we explore the relation across the different measures and price volatility. Some measures are computationally more difficult to estimate than others whereas some are more appropriate, from a theoretical point of view, to gauge liquidity. The examination of their relation can shed some light on these issues and provide evidence with practical implications for market participants and analysts. Principal component analysis is also employed in order to compare the different liquidity measures and verify their theoretical classification. This comparison will enable us to get a fairly good idea of the measures that best capture liquidity in the Greek market.

6.1. Correlation Analysis

In Tables 13-13A, we explore the relation across the various measures of liquidity for the ten-year benchmark bond by using simple statistical analysis, i.e. correlation coefficients. Table 13 shows the results for the pre euro area entry period while Table 13A for the post euro area entry period. The measures are calculated as weekly mean values whereas volatility as the standard deviation of trade-by-trade price changes over the week. The price impact coefficients are estimated from rolling regressions of trade-by-trade price changes on the net number of trades over the same interval.

There are important differences in the correlation coefficients of the various measures between the two periods. Those differences concern not only the size but also the direction of the variation between measures. For instance, trading frequency in the pre euro area entry period is positively related to the bid-ask spread and the price impact coefficient suggesting that increased activity was associated with reduced liquidity and market depth. Also, the trading volume appears dissociated

from volatility whereas the trade size exhibits strong negative correlation with price volatility. All those signs are reversed in the post euro area entry period. In the pre euro area entry period, the bid-ask spread measure is apparently the most appropriate to gauge liquidity. It is relatively strongly correlated with all other measures and the direction of the variation is, in each case, the expected one.

Focusing on the post euro area entry period (results in Table 13A), we observe that the bid-ask spread as well as the price impact coefficient appear as important measures of liquidity. They are both strongly correlated with most of the other measures and the estimated coefficients exhibit the expected signs. In addition, their correlation is high enough to render the one a relatively good proxy of the other. Trading volume and trading frequency are almost perfectly correlated, a fact that makes those two measures indistinguishable. This finding should be expected as the average trade size is very close to the minimum quote size imposed by regulation and, therefore, any increase in trading volume is a result of increased trading frequency. Another consequence of the latter is the relatively weak correlation of the trade size with each of the two measures of trading activity.

An important finding is that liquidity conditions in HDAT, as captured by the various measures estimated, are only moderately related to price volatility, i.e. there is a relatively weak correlation between volatility and all liquidity measures as shown in the first column of Table 13A[33]. As already mentioned, a number of empirical studies have established a significant link between volatility and trading activity that is not exactly confirmed in the present case. This leads us to conclude that activity, in addition to the bid-ask spread and the price impact coefficient, is an important gauge of liquidity in HDAT.

Trade size is a less important measure of liquidity. While in principle trade size is identified as a measure of both trading activity and market depth, our findings indicate that is weakly related to activity and even less so to market depth. Nevertheless, the negative sign of the correlation coefficient between trade size and the price impact coefficient in Table 13A is in line with the findings of the different studies mentioned earlier which indicate that larger trades have less impact on prices.

[33] For instance, in Fleming (2003) the correlation coefficients of trading frequency and price impact with price volatility are 0.71 and 0.84 respectively while for the bid-ask spread is 0.54. Similar results are shown in D'Souza, Gaa and Yang (2003).

The on/off-the-run yield spread is strongly correlated with volatility and trading activity whilst it appears only weakly related to the bid-ask spread and price impact coefficient. A narrower yield spread is associated with lower volatility but also with lower trading activity[34].

6.2. Principal-Component Analysis

A principal–component analysis (PCA) of the six different liquidity measures is conducted for the on-the-run ten-year bond in order to find additional evidence for the comparison of the various liquidity measures. As previously, we split the sample into the pre euro area entry and the post euro area entry period in order to identify clearly the changing patterns in the liquidity of the Greek bond market between those two periods. Our focus remains, however, on the post euro area entry period. The PCA basically allows us to detect the structure in the relationships between the liquidity measures (classification of variables) and to reduce the number of variables by combining two or more correlated variables into one factor.

In Tables 14 and 14A, the reported variances suggest that throughout the whole sample two factors have to be retained whereas the rest can be dropped. The first two components explain 80 percent of the standardized variance in the pre euro area entry period and 76 percent of the standardized variance in the post euro area entry period.

The two last rows (and columns) of Tables 13 and 13A report the correlation coefficients between the two principal-components and the liquidity measures. These figures give us a fairly good idea how the two principal components can be interpreted.

In the pre euro area entry period, according to the component matrix figures contained in Table 15, component one loads positively on bid-ask spread and negatively on trade size, suggesting that these two measures can be classified as one factor of variation in liquidity. During this period both the bid-ask spread and the minimum quote size were constantly adjusted with the evolution of the newly created market in terms of liquidity and market depth. The second component loads positively on trading activity (trading volume and frequency) suggesting that trading activity also constituted a factor explaining a significant part of the variation in liquidity.

[34] The yield spread, as pointed out previously, is found negative in our case and the negative sign of the correlation coefficient in Table 13A implies that the two measures move, indeed, in the same direction.

In the post euro area entry period, the interpretation of the first and second component is different (see Table 15A). In particular, component one loads positively on trading volume and trading frequency suggesting that trading activity, seen as one factor, explains a substantial part (55%, as shown in Table 14A) of liquidity variation. The second component loads positively on the bid-ask spread and price impact coefficient and explains an additional 21% of the variation in liquidity. There is, thus, a rather clear classification of the measures into one factor mainly capturing trading activity and a second factor capturing transaction costs and market depth. The trade size and the yield spread measures are not uniquely classified by PCA in either of the two factors, as they are equally present in both. The inability to classify the measure of trade size is not surprising since, by definition, it measures trading activity as well as market depth. The outcome of PCA concerning the yield spread measure may be, also, justified by its nature. The yield spread, as already pointed out, cannot be theoretically classified either as an activity or a market depth measure.

The PCA results provide supportive evidence for our findings from the preceding analysis. In the pre euro area entry period, the bid-ask spread (together with the trade size) was an important measure of liquidity in HDAT. During this period, trading activity measures were only of secondary importance. In the post euro area entry period, trading activity measures emerge as important proxies of liquidity that is also quite satisfactorily gauged by the bid-ask spread and the price impact coefficient measures.

7. How liquid is HDAT?

In this section we compare our estimates of the bid-ask spread and price impact coefficient for the ten-year benchmark bond with the respective figures obtained from studies of other government securities markets. Table 16 summarises the findings.

The difference between the spread of the ten-year benchmark bond in the Greek market and those observed in other markets is great. The average spread in HDAT, in the post euro area entry period, was almost four hundred times wider than the respective spread in the U.S. market and some one hundred times wider than the average spread observed in the four euro area countries included in Table 16,

indicating that the Greek market is far less liquid. Nevertheless, as has already been pointed out in detail, the Greek market has been constantly evolving so this unfavourable comparison should be thought of as limited only to the specific period covered by our sample. In fact, by the fall of 2004 when the writing of this study was completed, the bid-ask spread of the ten-year benchmark bond in HDAT shrunk to 2-3 bps, revealing a remarkable improvement in liquidity of the Greek market according to this specific measure.

According to the figures shown in Table 16 regarding the price impact coefficient, the U.S. market appears some one-hundred forty times deeper than its Greek counterpart while the Canadian market is some fifty-times deeper than HDAT as far as the ten-year benchmark bond is concerned[35]. There is, therefore, a disproportionality in the relative liquidity level revealed by the two different measures considered in this section that is hard to explain.

8. Conclusions

Since the launching of the Electronic Secondary Market for Securities (HDAT) in 1998, the Greek government securities market has been evolving as a two-tier market with HDAT at the core, forming market prices. The OTC market has retained a very significant part of total market trading activity, as the volume realised in it is several times the volume realised in HDAT, but the bulk of transactions are carried out at prices formed in HDAT. Being an organised trading venue operating under a specific regulatory framework, HDAT has been very successful in promoting efficiency in the secondary market for government securities.

We have examined liquidity in HDAT over the period 1999-2003, by estimating six different measures for each of the three- five- ten- and twenty-year benchmark bonds. Most measures show a substantial improvement of liquidity between the pre euro area entry and post euro area entry period. The ten-year benchmark bond appears, by any of the measures employed, as the most liquid one among the four benchmark bonds considered. We compared our estimates of the various liquidity measures in order to assert their appropriateness in the case of HDAT. The bid-ask spread is the most important measure of liquidity in the pre euro

area entry period but looses considerable part of its power in the post euro area entry period. Its significance as an appropriate liquidity measure, however, is reinforced by the fact that the information asymmetry component in it is expected to be limited. The latter is supported by the nature of the traded securities as well as by the way HDAT is organised.

Among the different measures considered, the price impact coefficient is the most sophisticated one. It emerges as an important measure of liquidity, particularly in the post euro area entry period. The bid-ask spread and the price impact coefficient measures are correlated to a significant extend (correlation coefficient 0.56). It can, thus, be concluded that in practice, quite safely, the easily observable bid-ask spread may be used instead of the impact coefficient that is not readily available and is rather difficult to estimate.

Trading activity in HDAT is found to be only weakly related to price volatility and this is a result contrary to the findings of other relevant empirical studies in the literature. It can probably be explained by the two-tier structure of the Greek secondary market. Due to the observed weak relation between volatility and trading activity, the latter emerges as a meaningful proxy of liquidity in HDAT both in the pre and post euro area entry period. Furthermore, trading activity is best captured by trading frequency because the trade size in HDAT is usually closed to the minimum quote size imposed by regulation and thus any change in trading volume is predominately caused by a change in trading frequency.

The two-tier structure of the market also explains the inappropriateness of trade size as a proxy of market depth, at least in the post euro area entry period during which the minimum quote size has remained constant. Our comparative analysis fails to classify clearly the trade size measure either as an activity or a market depth measure, and, there are reasons to believe that this is not merely the result of the dual nature of this measure but that it also reveals the measure's inability to capture accurately either the changes in activity or in market depth.

Finally, the on/off-the-run yield spread measure, though presented in our study and included in comparative analysis of the various measures undertaken, appears a poor measure of liquidity in HDAT mainly because different factors, such as the relatively infrequent issuances of new benchmark bonds, confound its interpretation.

[35] Note that in the U.S. and Canada the most liquid security is the two-year benchmark and not the ten-year benchmark as is the case for HDAT.

A strong relationship between order flow and price changes was detected. In fact, the R^2 statistic of the simple models for the ten-year bond presented in Table 12 has quite high values. It reaches 26 percent when the net number of trades is used as explanatory variable.

Significant commonality in liquidity across securities and measures was found only regarding trading volume and trading frequency. On the contrary, a relatively low correlation across securities was detected regarding the bid-ask spread and the trade size measures.

References

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

Amihud, Y., Mendelson, H., (1986), "Asset Pricing and the Bid-Ask Spread", *Journal of Financial Economics*, 17, 223-249.

Amihud, Y., Mendelson, H., (1989), "The Effects of Beta, Bid-Ask Spread, Residual Risk and Size on Stock Returns", *Journal of Finance*, 44, 479-486.

Amihud, Y., Mendelson, H., (1991), "Liquidity, Maturity, and the Yields on U.S. Treasury Securities", *Journal of Finance*, 46(4), 1411-25.

Cao, C., Field, L. C., Hanka G., (2004) "Does Insider Trading Impair Market Liquidity? Evidence from IPO Lockup Expirations", *Journal of Financial and Quantitative Analysis*, 39 (1), 25-46.

Chan, K., Fong, W. M., (2000), "Trade Size, Order Imbalance, and the Volatility-Volume Relation", *Journal of Financial Economics,* 57, 247-273.

Cheung, Y., De Jong, F., Rindi, B., (2003)" Trading European Sovereign Bonds: The Microstructure of the MTS Trading Platforms", EFA Annual Conference Paper no. 245.

Downing, C., Zhang, F., (2004), "Trading Activity and Price Volatility in the Municipal Bond Market", *Journal of Finance*, 45(2).

Daves, P. R., Erhardt, M. C., (1993) "Liquidity, Reconstitution, and the Value of U.S. Treasury Strips," *Journal of Finance,* 48 (1), 315-329.

D'Souza, C., Gaa, C., Yang, J., (2003), "An Empirical Analysis of Liquidity and Order Flow in the Brokered Interdealer Market for Government of Canada Bonds", *Bank of Canada Working Paper,* no. 28.

Duffie, D., (1996), "Special Repo Rates", *Journal of Finance*, 51(2), 493-526.

Favero, C., Pagano M., von Thadden, E-L., (2004), "Valuation, Liquidity and Risk in Government Bond Markets", Paper presented in the Symposium of the ECB-CFS Research Network, Frankfurt, May 10-11.

Fleming, M., (2003), "Measuring Treasury Market Liquidity", Federal Reserve Bank of New York, *Economic Policy Review,* September.

Furfine, C. H., Remolona E. M., (2002), "What's Behind the Liquidity Spread? On-the-Run and Off-the-Fun U.S. Treasuries in Autumn 1998", BIS *Quarterly Review*, June 51-8.

Harris, L., (1987), "Transactions Data Tests of the Mixture of Distributions Hypothesis", *Journal of Financial and Quantitative Analysis*, 22, 127-141.

Harris, M., Raviv, A., (1993) "Differences of Opinion Make a Horse Race", *Review of Financial Studies,* 6, 473-506.

Hasbrouck, J. (1993), "Assessing the Quality of a Security Market: A new Approach to Transaction-Cost Measurement", *The Review of Financial Studies*, 6(1), 191-212

Glosten, L., Harris, L., (1988), "Estimating the Components of the Bid-Ask Spread", *Journal of Financial Economics*, 21, 123-142.

Goldreich, D., Hanke, B., Nath, P., (2003) "The Price of Future Liquidity: Time-Varying Liquidity in the U.S. Treasury Market", *CEPR Discussion Paper. No 3900*. London, Centre for Economic Policy Research.

Grossman, S.J., and Miller, M.H., (1988) "Liquidity and Market Structure", *Journal of Finance*, 43, 617-633.

Grundy, B., McNichols, M., (1989) "Trade and Revelation of Information Through Prices and Direct Disclosure", *Review of Financial Studies*, 2, 495-526.

Holden, C. W., Subrahmanyam, A., (1992), "Long-lived Private Information and Imperfect Competition", *Journal of Finance*, 47, 247-270.

Huang, R., Cai, J., Wang, X., (2002) "Inventory Risk-Sharing and Public Information–Based Trading in the Treasury Note Interdealer Broker Market", *Journal of Financial Intermediation*, 11 (3), 383-411.

Jones, C., Kaul, G., Lipson, M., (1994), "Transactions, Volume and Volatility", *Review of Financial Studies*" 7, 631-652.

Kamara, A., (1994), "Liquidity, Taxes and Short–Term Treasury Yields", *Journal of Financial and Quantitative Analysis,* 29(3), 403-417.

Karpoff, J. M. (1987), "The Relation Between Price Changes and Trading Volume: A Survey", *Journal of Financial and Quantitative Analysis*, 22, 109-26.

Kyle, A., (1985), "Continuous Auctions and Insider Trading", *Econometrica*, 53, 1315-1335.

Madhavan, A., Richardson, M., Roomans, M., (1997), "Why Do Stock Prices Move? A Transactions–Based Analysis of NYSE Stocks", *Review of Financial Studies*, 10, 1035-1064.

Meneu, V., Pardo, A., (2004), "Pre-holiday Effect, Large Trades and Small Investor Behaviour", *Journal of Empirical Finance*, 11, 231-246.

O'Hara, M., (1995), "Market Microstructure Theory", Cambridge, MA: Blackwell Business.

Shalen, C. T., (1993), "Volume, Volatility and the Dispersion of Beliefs", *The Review of Financial Studies*, 6, 405-434

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

Strebulaev, I., (2001), "Market Imperfections and Pricing in the U.S. Treasury Securities Market", *London Business School,* IFA *Working Paper.*

Tauchen, G., Pitts, M., (1983), "The Price Variability-Volume Relationship on Speculative Markets", *Econometrica,* 51, 485-505.

Warga, A., (1992), "Bond Return, Liquidity, and Missing Data", *Journal of Financial and Quantitative Analysis*, 27, 606-617.

TABLE 1: Daily Trading Volume for Greek Government Bonds (entire sample)

Issue	*Mean*	*Median*	*Standard Deviation*
Three-year bond	67.8	35	90.4
Five-year bond	139.7	90	144.3
Ten-year bond	208.3	120	245.2
Twenty-year bond	151.4	135	109.7

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on daily trading volume in HDAT for the indicated on-the-run securities in millions of euros. The sample period is January 1999 to November 2003 except for the twenty-year bond for which the sample begins on 12 January 2000.

TABLE 1A: Daily Trading Volume for Greek Government Bonds (sub-samples)

Issue	*Mean*		*Median*		*Standard Deviation*	
	Pre euro	Post euro	Pre euro	Post euro	Pre euro	Post euro
Three-year bond	15.9	85.6	8.8	60	20.4	97.9
Five-year bond	19.3	193.2	11.7	170	19.1	143.5
Ten-year bond	38.7	312.7	29.3	237.5	35.2	260.4
Twenty-year bond	38.4	183.3	23.5	170	43.3	101.3

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on daily trading volume in HDAT for the indicated on-the-run securities in millions of euros. The pre euro area entry sample period is January 1999 to December 2000 while for the post euro entry period the sample ranges from January 2001 to November 2003.

TABLE 2: Daily Trading Frequency of Greek Government Bonds (entire sample)

Issue	*Mean*	*Median*	*Standard Deviation*
Three-year bond	11.1	7.0	13.1
Five-year bond	24.3	17.0	23.4
Ten-year bond	37.6	24.0	51.5
Twenty-year bond	29.5	26.0	21.7

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on the daily number of trades in HDAT for the indicated on-the-run securities. The sample period is January 1999 to November 2003 except for the twenty-year bond for which the sample begins on 12 January 2000.

TABLE 2A: Daily Trading Frequency for Greek Government Bonds (sub-samples)

Issue	*Mean*		*Median*		*Standard Deviation*	
	Pre euro	Post euro	Pre euro	Post euro	Pre euro	Post euro
Three-year bond	3.4	13.7	2.0	10.0	3.5	14.1
Five-year bond	4.5	33.1	3.0	30.0	4.7	23.0
Ten-year bond	8.9	55.3	6.0	44.0	8.1	43.9
Twenty-year bond	6.5	36.0	4.0	33.0	7.3	20.0

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on daily number of trades in HDAT for the indicated on-the-run securities. The pre euro area entry sample period is January 1999 to December 2000 while for the post euro area entry period the sample ranges from January 2001 to November 2003.

TABLE 3: Trade Sizes of Greek Government Bonds (entire sample)

Issue	*Mean*	*Median*	*Standard Deviation*
Three-year bond	5.7	5.0	2.5
Five-year bond	5.3	5.4	1.3
Ten-year bond	5.2	5.3	1.2
Twenty-year bond	5.3	5.0	0.6

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on mean daily trade sizes in HDAT for the indicated on-the-run securities in millions of euros. The sample period is January 1999 to November 2003 except for the twenty-year bond for which the sample begins on 12 January 2000.

TABLE 3A: Trade Sizes of Greek Government Bonds (sub-samples)

Issue	*Mean*		*Median*		*Standard Deviation*	
	Pre euro	Post euro	Pre euro	Post euro	Pre euro	Post euro
Three-year bond	4.6	6.1	2.9	5.2	3.2	2.1
Five-year bond	4.5	5.7	5.9	5.4	1.5	1.0
Ten-year bond	4.6	5.5	5.9	5.3	1.5	0.8
Twenty-year bond	5.9	5.1	5.9	5.0	0.3	0.5

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on mean daily trade sizes in HDAT for the indicated on-the-run securities in millions of euros. The pre euro area entry sample period is January 1999 to December 2000 while for the post euro area entry period the sample ranges from January 2001 to November 2003.

TABLE 4: On-the-Run/Off-the-Run Yield Spreads of Greek Government Bonds (entire sample)

Issue	*Mean*	*Median*	*Standard Deviation*
Three-year bond	-18.27	-9.85	30.67
Five-year bond	-28.36	-31.50	16.50
Ten-year bond	-5.49	-5.50	5.10
Twenty-year bond	-10.05	-9.55	5.83

Source: Authors' calculations, based on data from BLOOMBERG.
Notes: The table reports descriptive statistics on daily on-the-run/off-the-run yield spreads for the indicated securities in basis points. The sample period is May 2000 to November 2003 except for the twenty-year bond where the sample begins on April 2002.

TABLE 4A: On-the-Run/Off-the-Run Yield Spreads of Greek Government Bonds (sub-samples)

Issue	*Mean*		*Median*		*Standard Deviation*	
	Pre euro	Post euro	Pre euro	Post euro	Pre euro	Post euro
Three-year bond	13.48	-29.54	15.40	-28.70	7.94	27.69
Five-year bond	-31.52	-27.66	-31.70	-30.75	1.40	18.13
Ten-year bond	-10.45	-4.40	-10.45	-4.30	2.11	4.92
Twenty-year bond	-	-10.05	-	-9.55	-	5.83

Source: Authors' calculations, based on data from BLOOMBERG.
Notes: The table reports descriptive statistics on daily on-the-run/off-the-run yield spreads for the indicated securities in basis points. The pre euro area entry sample period is May 2000 to December 2000 while for the post euro area entry period the sample ranges from January 2001 to November 2003. Relevant data for the twenty-year bond cover only the period from April 2002 to November 2003.

TABLE 5: Bid-Ask Spreads of Greek Government Bonds (entire sample)

Issue	*Mean*	*Median*	*Standard Deviation*
Three-year bond	15.84	7.14	13.48
Five-year bond	15.93	8.61	13.61
Ten-year bond	17.62	10.0	12.63
Twenty-year bond	14.82	14.63	3.57

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on mean daily bid-ask spreads in HDAT for the indicated on-the-run securities in basis points. The sample period is January 1999 to November 2003 except for the twenty-year bond where the sample begins on 12 January 2000.

TABLE 5A: Bid-Ask Spreads of Greek Government Bonds (sub-samples)

Issue	*Mean*		*Median*		*Standard Deviation*	
	Pre euro	Post euro	Pre euro	Post euro	Pre euro	Post euro
Three-year bond	28.86	7.09	25.0	7.0	12.89	1.29
Five-year bond	29.21	6.97	25.0	6.9	12.68	1.52
Ten-year bond	29.78	9.34	25.0	9.74	11.98	1.03
Twenty-year bond	19.28	13.53	20.0	14.46	4.19	2.0

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on mean daily bid-ask spreads in HDAT for the indicated on-the-run securities in basis points. The pre euro area entry sample period is January 1999 to December 2000 while for the post euro area entry period the sample ranges from January 2001 to November 2003.

TABLE 6: Daily Net Trading Volume in Greek Government Bonds (entire sample)

Issue	*Mean*	*Median*	*Standard Deviation*
Three-year bond	-0.8	0.0	41.6
Five-year bond	-0.3	2.9	57.9
Ten-year bond	-3.1	0.0	68.1
Twenty-year bond	-1.3	0.0	51.1

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on daily net trading volume in HDAT for the indicated on-the-run securities in millions of euros. Net trading volume equals buyer-initiated less seller-initiated volume. The sample period is January 1999 to November 2003 except for the twenty-year bond where the sample begins on 12 January 2000.

TABLE 6A: Daily Net Trading Volume in Greek Government Bonds (sub-samples)

Issue	*Mean*		*Median*		*Standard Deviation*	
	Pre euro	Post euro	Pre euro	Post euro	Pre euro	Post euro
Three-year bond	0.0	-1.0	2.9	0.0	18.4	47.0
Five-year bond	1.0	-0.9	2.9	0.0	18.0	68.6
Ten-year bond	0.6	-5.3	0.0	-5.0	27.6	83.8
Twenty-year bond	4.5	-3.0	5.9	0.0	31.7	55.3

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on daily net trading volume in HDAT for the indicated on-the-run securities in millions of euros. Net trading volume equals buyer-initiated less seller-initiated volume. The pre euro area entry sample period is January 1999 to December 2000 while for the post euro area entry period the sample ranges from January 2001 to November 2003.

TABLE 7: Daily Net Number of Trades in Greek Government Bonds (entire sample)

Issue	*Mean*	*Median*	*Standard Deviation*
Three-year bond	-0.1	0.0	6.3
Five-year bond	0.0	0.0	9.0
Ten-year bond	-0.5	0.0	11.6
Twenty-year bond	-0.4	0.0	9.8

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on the daily net number of trades in HDAT for the indicated on-the-run securities. The net number of trades equals buyer-initiated less seller-initiated trades. The sample period is January 1999 to November 2003 except for the twenty-year bond where the sample begins on 12 January 2000.

TABLE 7A: Daily Net Number of Trades in Greek Government Bonds (sub-samples)

Issue	*Mean*		*Median*		*Standard Deviation*	
	Pre euro	Post euro	Pre euro	Post euro	Pre euro	Post euro
Three-year bond	-0.1	-0.1	1.0	0.0	3.5	7.0
Five-year bond	0.1	0.0	1.0	0.0	4.2	10.5
Ten-year bond	0.1	-0.9	0.0	0.0	6.3	13.8
Twenty-year bond	0.8	-0.8	1.0	0.0	5.4	10.7

Source: Authors' calculations, based on data from the HDAT
Notes: The table reports descriptive statistics on the daily net number of trades in HDAT for the indicated on-the-run securities. The net number of trades equals buyer-initiated less seller-initiated trades. The pre euro area entry sample period is January 1999 to December 2000 while for the post euro area entry period the sample ranges from January 2001 to November 2003.

TABLE 8: Regression results

Impact of Trades on Prices (Daily changes)
10 year Bond in the pre euro entry period
Number of observations : 439 / Standard errors in parentheses.

Independent Variables	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5
Net number of Trades	0.0380			0.0816	
	(0.0039)			(0.0011)	
Net Trading Volume		0.0007		-0.0001	
		(0.00009)		(0.00002)	
Proportion of buyer-initiated trades			0.5297		
			(0.00534)		
Number of buyer-initiated trades					0.0409
					(0.0051)
Number of seller-initiated trades					-0.0348
					(0.0044)
Constant	0.0051	0.0040	-0.2610	0.0079	-0.0219
	(0.0178)	(0.0190)	(0.00332)	(0.0172)	(0.0259)
Adjusted R^2	0.29	0.19	0.18	0.34	0.29

The standard errors were computed with White- Heteroscedasticity Consistent Covariances.

TABLE 9: Regression results

Impact of Trades on Prices (Daily changes)
10 year Bond in the post euro entry period
Number of observations: 708 / Standard errors in parentheses

Independent Variables	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5
Net number of Trades	0.0078			0.0185	
	(0.00084)			(0.00330)	
Net Trading Volume		0.0001		-0.0002	
		(0.00001)		(0.00005)	
Proportion of buyer-initiated trades			0.6265		
			(0.07457)		
Number of buyer-initiated trades					0.0069
					(0.00090)
Number of seller-initiated trades					-0.0095
					(0.00090)
Constant	0.0133	0.0124	-0.2995	0.0130	0.0838
	(0.01171)	(0.01187)	(0.03828)	(0.01162)	(0.01865)
Adjusted R^2	0.11	0.08	0.09	0.12	0.14

TABLE 10: Regression results

Impact of Trades on Prices (Trade-by-trade changes)
10 year Bond in the pre euro entry period
Number of observations: 3,871 / Standard errors in parentheses.

Independent Variables	Regression 1	Regression 2	Regression 3	Regression 4
Net number of Trades	0.0477			0.0833
	(0.00194)			(0.00577)
Net Trading Volume		0.0009		-0.0008
		(0.00004)		(0.00001)
Proportion of buyer-initiated trades			0.0953	
			(0.00387)	
Number of buyer-initiated trades				
Number of seller-initiated trades				
Constant	0.0012	0.0010	-0.0465	0.0014
	(0.00194)	(0.00198)	(0.00274)	(0.00019)
Adjusted R^2	0.14	0.10	0.14	0.15

The standard errors were computed with White- Heteroscedasticity Consistent Covariances.

TABLE 11: Regression results

Impact of Trades on Prices (Trade-by-trade changes)
10 year Bond in the post euro entry period
Number of observations: 39,211 / Standard errors in parentheses.

Independent Variables	Regression 1	Regression 2	Regression 3	Regression 4
Net number of Trades	0.0149			0.0181
	(0.00022)			(0.00050)
Net Trading Volume		0.0002		-0.0006
		(0.00004)		(0.00008)
Proportion of buyer-initiated trades			0.0298	
			(0.00044)	
Number of buyer-initiated trades				
Number of seller-initiated trades				
Constant	0.0004	0.0003	-0.0146	0.0004
	(0.00022)	(0.00002)	(0.00031)	(0.00022)
Adjusted R^2	0.11	0.08	0.11	0.11

TABLE 12: Regression results

Impact of Trades on Prices (Hourly changes)
10 year bond / Sample period 2002-2003
Number of observations: 1,714 / Standard errors in parentheses.

Independent Variables	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5
Net number of Trades	0.00853			0.01560	
	(0.000455)			(0.001225)	
Net Trading Volume		0.00001		-0.00001	
		(0.000001)		(0.000002)	
Proportion of buyer-initiated trades			0.15010		
			(0.007936)		
Number of buyer-initiated trades					0.00800
					(0.000450)
Number of seller-initiated trades					-0.00926
					(0.000532)
Constant	-0.00220	-0.00165	-0.07707	-0.00255	0.00588
	(0.001975)	(0.002044)	(0.004980)	(0.000194)	(0.002592)
Adjusted R^2	0.26	0.19	0.17	0.28	0.26

The standard errors were computed with White- Heteroscedasticity Consistent Covariances.

TABLE 13: Correlation of Liquidity Measures

10 year Bond in the pre euro entry period
Frequency of observations: Weekly

Measure	Price Volatility	Trading Volume	Trading Frequency	Bid- Ask Spread	Trade Size	Price Impact	PCA 1	PCA2
Price Volatility	1.000	-0.087	0.239	0.624	-0.595	0.223	0.587	0.208
Trading Volume	-0.087	1.000	0.773	-0.312	0.310	-0.163	-0.476	0.857
Trading Frequency	0.239	0.773	1.000	0.229	-0.282	0.013	0.094	0.984
Bid- Ask Spread	0.624	-0.312	0.229	1.000	-0.904	0.420	0.943	0.160
Trade Size	-0.595	0.310	-0.282	-0.904	1.000	-0.264	-0.931	-0.194
Price Impact	0.223	-0.163	0.013	0.420	-0.264	1.000	0.503	-0.033
Principal Component 1 (PCA 1)	0.587	-0.476	0.094	0.943	-0.931	0.503	1.000	0.000
Principal Component 2 (PCA 2)	0.208	0.857	0.984	0.160	-0.194	-0.033	0.000	1.000

TABLE 13A: Correlation of Liquidity Measures

10 year Bond in the post euro entry period
Frequency of observations: Weekly

Measure	Price Volatility	Trading Volume	Trading Frequency	Bid- Ask Spread	Trade Size	Price Impact	Yield spread	PCA 1	PCA 2
Price Volatility	1.000	0.220	0.222	0.126	0.152	0.161	-0.403	0.178	0.376
Trading Volume	0.220	1.000	0.993	-0.548	0.398	-0.499	-0.580	0.947	0.019
Trading Frequency	0.222	0.993	1.000	-0.545	0.305	-0.496	-0.551	0.925	-0.034
Bid- Ask Spread	0.126	-0.548	-0.545	1.000	-0.252	0.557	0.120	-0.685	0.478
Trade Size	0.152	0.398	0.305	-0.252	1.000	-0.144	-0.514	0.540	0.530
Price Impact	0.161	-0.499	-0.496	0.557	-0.144	1.000	0.104	-0.640	0.563
Yield spread	-0.403	-0.580	-0.551	0.120	-0.514	0.104	1.000	-0.629	-0.638
Principal Component 1 (PCA 1)	0.178	0.947	0.925	-0.685	0.540	-0.629	-0.640	1.000	0.000
Principal Component 2 (PCA 2)	0.376	0.019	-0.034	0.478	0.530	0.563	-0.638	0.000	1.000

Table 14: Principal Component Analysis

	Total Variance Explained (pre euro entry period)		
Component	Eigenvalues	% Variance	Cumulative %
1	2.25	44.90	44.90
2	1.77	35.32	80.22
3	0.84	16.86	97.08

Table 14A: Principal Component Analysis

	Total Variance Explained (post euro entry period)		
Component	Eigenvalues	% Variance	Cumulative %
1	3.32	55.28	55.28
2	1.23	20.56	75.84
3	0.71	11.75	87.59

Table 15: Principal Component Analysis

Liquidity Measures	Component Matrix (pre euro entry period)	
	Component	
	1	2
Trading Volume	-0.476	0.857
Trading Frequency	0.094	0.984
Bid Ask	0.943	0.160
Trade Size	-0.931	-0.194
Price Impact	0.503	-0.033

Table 15A: Principal Component Analysis

Liquidity Measures	Component Matrix (post euro entry period)	
	Component	
	1	2
Trading Volume	0.947	0.019
Trading Frequency	0.925	-0.034
Bid Ask	-0.685	0.478
Trade Size	0.540	0.530
Price Impact	-0.629	0.563
Yield spread	-0.640	-0.638

Table 16: Comparing liquidity in different markets
(Results for the ten-year benchmark bond)

Market	Bid-ask spread[(1)]	Price impact[(2)]
U.S.[(3)]	0.024	161.9
Canada[(4)]	0.076	63.5
Germany[(5)]	0.088	n.a
France[(5)]	0.092	n.a
Italy[(5)]	0.076	n.a
Belgium[(5)]	0.082	n.a
Greece	9.34	1.18

(1): Average spread in bps
(2): Net number of trades required to move the price of 10Y bond by 1 bps
(3): From Fleming (2003). Sample period Dec. 1996-March 2000.
(4): From D'Souza, Gaa and Young (2003). Sample period Feb. 2002-Feb. 2003.
(5): From Cheung, de Jong and Rindi (2003). Sample period Jan. 2001-May 2002.

CHART 1

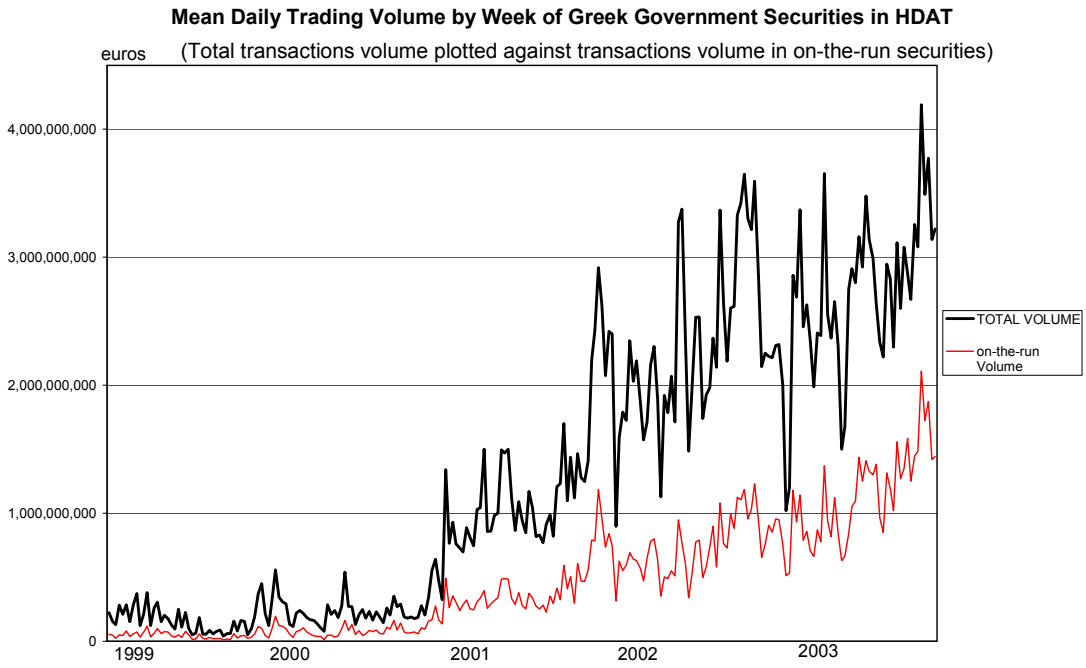


CHART 2

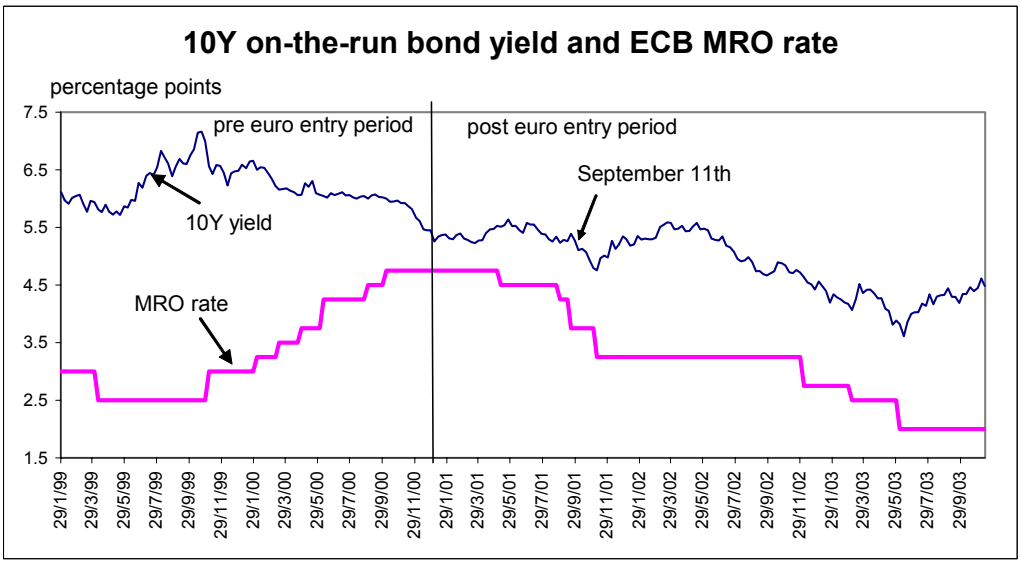


CHART 3

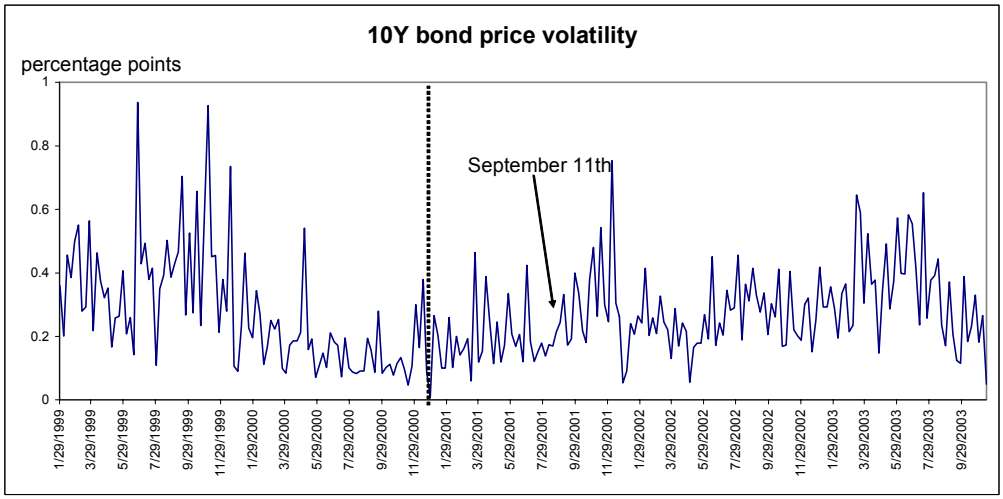


CHART 4

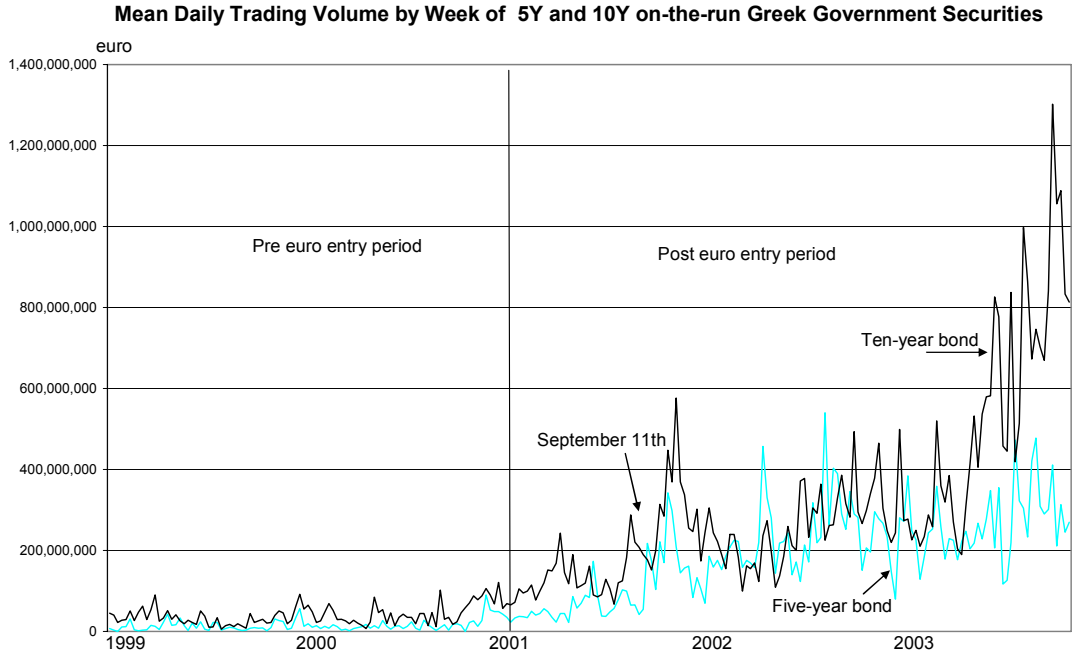


CHART 5

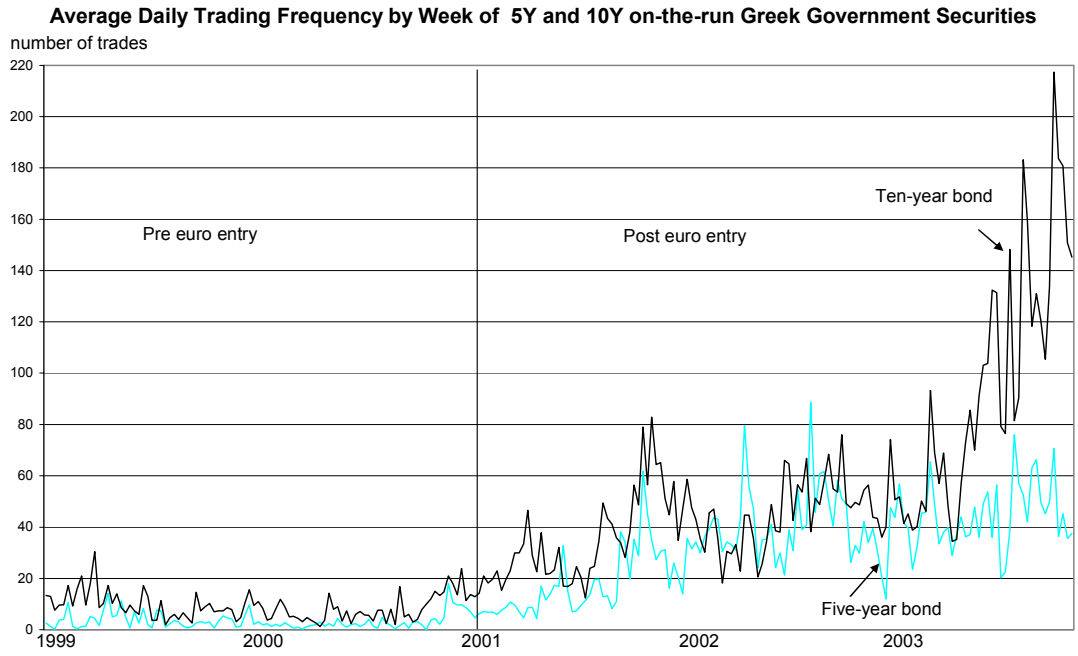


CHART 6

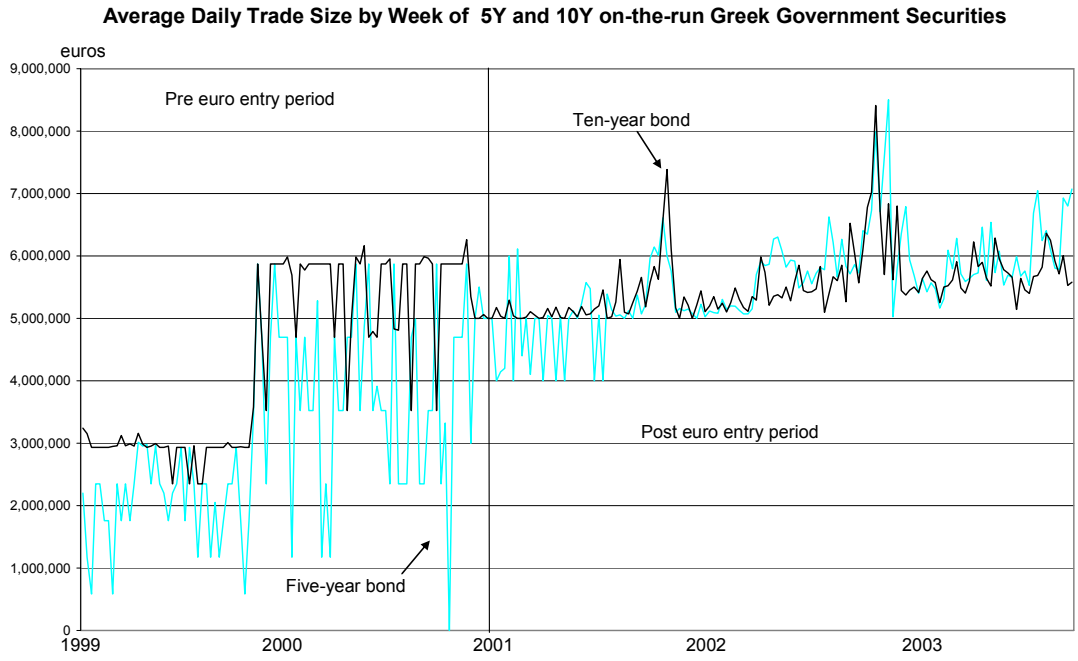


CHART 7

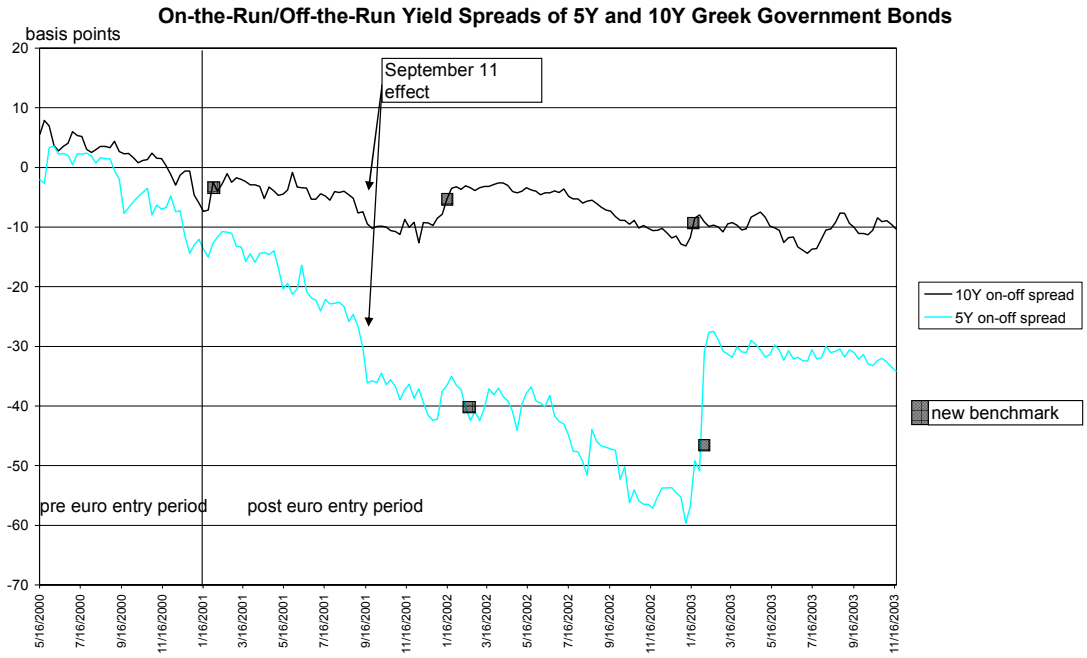


CHART 8

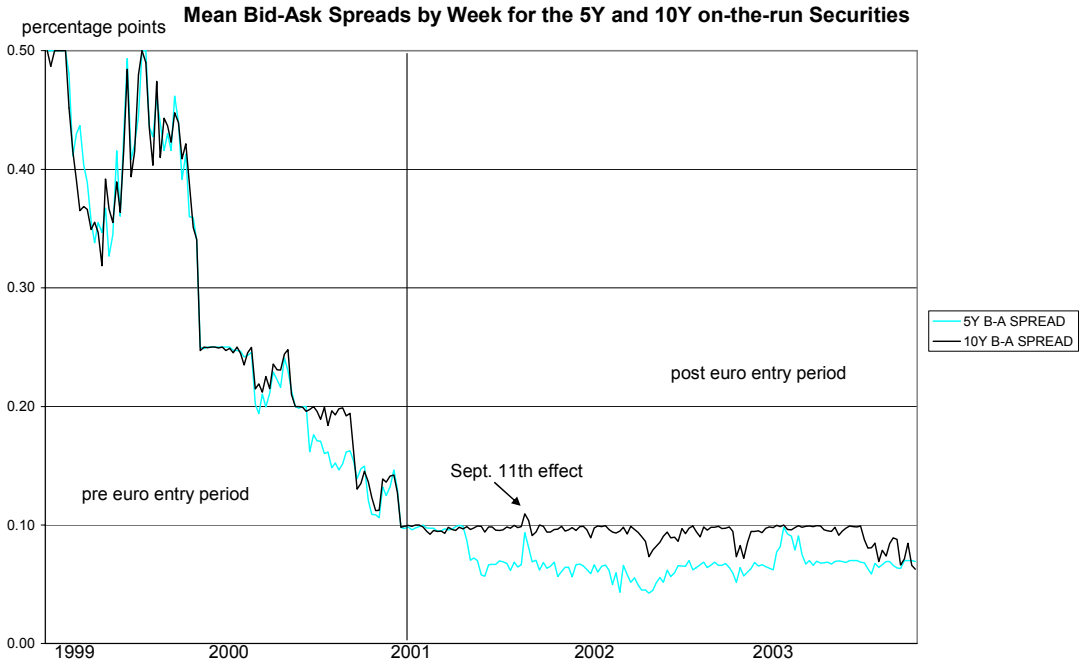
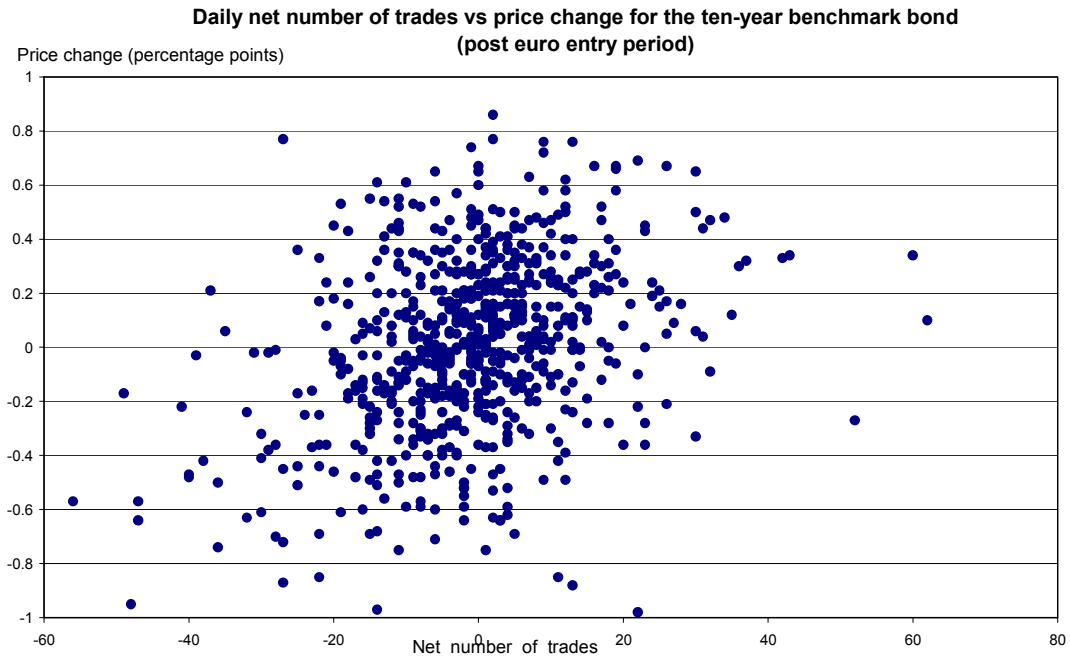


CHART 9


Daily net number of trades vs price change for the ten-year benchmark bond
(post euro entry period)
Price change (percentage points)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-60
-40
-20
0
20
40
60
80
Net number of trades

BANK OF GREECE WORKING PAPERS

1. Brissimis, S. N., G. Hondroyiannis, P.A.V.B. Swamy and G. S. Tavlas, "Empirical Modelling of Money Demand in Periods of Structural Change: The Case of Greece", February 2003.

2. Lazaretou, S., "Greek Monetary Economics in Retrospect: The Adventures of the Drachma", April 2003.

3. Papazoglou, C. and E. J. Pentecost, "The Dynamic Adjustment of a Transition Economy in the Early Stages of Transformation", May 2003.

4. Hall, S. G. and N. G. Zonzilos, "An Indicator Measuring Underlying Economic Activity in Greece", August 2003.

5. Brissimis, S. N. and N. S. Magginas, "Changes in Financial Structure and Asset Price Substitutability: A Test of the Bank Lending Channel", September 2003.

6. Gibson, H. D. and E. Tsakalotos, "Capital Flows and Speculative Attacks in Prospective EU Member States", October 2003.

7. Milionis, A. E., "Modelling Economic Time Series in the Presence of Variance Non-Stationarity: A Practical Approach", November 2003.

8. Christodoulopoulos, T. N. and I. Grigoratou, "The Effect of Dynamic Hedging of Options Positions on Intermediate-Maturity Interest Rates", December 2003.

9. Kamberoglou, N. C., E. Liapis, G. T. Simigiannis and P. Tzamourani, "Cost Efficiency in Greek Banking", January 2004.

10. Brissimis, S. N. and N. S. Magginas, "Forward-Looking Information in VAR Models and the Price Puzzle", February 2004.

11. Papaspyrou, T., "EMU Strategies: Lessons From Past Experience in View of EU Enlargement", March 2004.

12. Dellas, H. and G. S. Tavlas, "Wage Rigidity and Monetary Union", April 2004.

13. Hondroyiannis, G. and S. Lazaretou, "Inflation Persistence During Periods of Structural Change: An Assessment Using Greek Data", June 2004.

14. Zonzilos, N., "Econometric Modelling at the Bank of Greece", June 2004.

15. Brissimis, S. N., D. A. Sideris and F. K. Voumvaki, "Testing Long-Run Purchasing Power Parity under Exchange Rate Targeting", July 2004.

16. Lazaretou, S., "The Drachma, Foreign Creditors and the International Monetary System: Tales of a Currency During the 19th and the Early 20th Century", August 2004.

17. Hondroyiannis G., S. Lolos and E. Papapetrou, " Financial Markets and Economic Growth in Greece, 1986-1999", September 2004.

18. Dellas, H. and G. S. Tavlas, "The Global Implications of Regional Exchange Rate Regimes", October 2004.

19. Sideris, D., "Testing for Long-run PPP in a System Context: Evidence for the US, Germany and Japan", November 2004.

20. Sideris, D. and N. Zonzilos, "The Greek Model of the European System of Central Banks Multi-Country Model", February 2005.

21. Kapopoulos, P. and S. Lazaretou, "Does Corporate Ownership Structure Matter for Economic Growth? A Cross - Country Analysis", March 2005.

22. Brissimis, S. N. and T. S. Kosma, "Market Power Innovative Activity and Exchange Rate Pass-Through", April 2005.