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Empirical Essays on Corporate Finance and Government Bond Markets

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Contents

CHAPTER 1

DO FINANCING OBSTACLES HAMPER FIRM GROWTH? EVIDENCE ON EURO AREA NON FINANCIAL CORPORATIONS*

Abstract

This paper investigates whether financial factors, along with firms' characteristics, significantly affect firm growth using an unbalanced panel of about 1,000,000 observations for around 155,000 non-financial corporations in five Euro area countries. In addition to the balance sheet information in the panel, I also rely on firm-level survey data. In this way it is possible to work out a direct measure of the firms' probability of facing financing obstacles. Furthermore, I find that firm growth is not due to chance and that financial position matter. Although the evidence that firm cash flow and growth opportunities positively affect growth is unambiguous, I obtain less clear-cut results for leverage and debt burden ratios. Moreover, even if the direct measure of financing obstacles is a function of qualitative indicators, it is able to capture the negative impact of financing obstacles on firm growth in four countries.

Keywords: Financing Constraints, Firm Growth, Panel Data.

JEL Classification: C23, E22, G32, L11.

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1. Introduction

Studying firm growth can provide insights into the dynamics of the competitive process, strategic behaviour, the evolution of market structure, and, perhaps, even the growth of the aggregate economy (Carpenter and Petersen, 2002). However, there are just a few studies that examine the finance-growth nexus at the firm level. As surveyed by Wachtel (2003), Levine (2005) and Papaioannou (2007), usually they assess the effect of well-developed financial markets in relaxing firm's financing constraints and do not address directly the role of financing constraints on growth. Even when financing constraints are investigated, the focus is on firms' investment choices and it is only indirectly proved that they affect investment decisions and then firms growth (Hubbard, 1998).

This study aims at providing a useful contribution to the understanding of the main factors affecting firm growth, and insights on the importance of enhancing firms' funding opportunities. Its main contribution is the direct measurement of the impact of firms' financial position and access to finance on growth. In doing this, it also adds to the literature on both stochastic and deterministic approaches to explain the determinants of firm size. With respect to the former, I refer to the Law of Proportionate Effects (LPE) (Gibrat, 1931), that states that firm growth is independent of initial size and past growth rates. Both Sutton (1997) and Hart (2000) survey the empirical tests of LPE and the earlier literature trying to explain the departure from this law. This departure was also explained in terms of financing constraints (Cooley and Quadrini, 2001; Cabral and Mata, 2003; Albuquerque and Hopenhayn, 2004; Clementi and Hopenhayn, 2006). Asymmetric information and financing constraints are also considered in the deterministic approach, as reviewed by Schiantarelli (1996), Hubbard (1998) and Stein (2003). Through the estimation of an augmented version of the standard LPE equation I jointly test the implications of both strands of literature.

The novelty of this research is to make use of the survey data advantages to overcome balance sheet data shortcomings and vice versa. On the one hand, surveys might be affected by self-reporting bias, but, on the other hand, they provide qualitative and direct information on the firms' situation that cannot be derived from balance sheet data. The latter offer relevant information on the firms' financial position itself, although both cash flow (as in Fazzari, Hubbard and Petersen, 1988) and other balance sheet based indexes (as in Kaplan and Zingales, 1997b, and Whited and Wu, 2006) may either be a bad proxy for the access to the loan market or capture effects not related to liquidity constraints. Hence, I construct a direct indicator of financing obstacles reported by firms from firm-level survey data (WBES by the World Bank, 2000), which can be used to exploit the richness of information of a larger panel dataset.

As in Carpenter and Petersen (2002), I investigate the impact of cash flow on firm growth. Furthermore, referring to Bernanke, Gertler and Gilchrist (1996), Lang, Ofek and Stulz (1996) and Nickell and Nicolitsas (1999), I contribute to the literature on financial distress and firm performance by including variables such as the indebtedness level or the debt burden that can affect the external finance premium faced by firms. With respect to the econometric methods, I apply dynamic panel data techniques as in Oliveira and Fortunato (2006b) and Hutchinson and Xavier (2006).

Another major difference with earlier literature is that my dataset includes mainly non-listed and small and medium-sized firms. In particular, I use a panel dataset of around 1 million firm-year observations, 95% of them being SMEs, in five euro area non-financial corporations (namely France, Germany, Italy, Portugal and Spain). This is a clear advantage with respect to most previous studies, since these are the firms expected to be more affected by financing constraints, and are the backbone of the EU's non-financial business economy.[1]

After controlling for growth opportunities, as well as time and sectoral effects, I analyze the impact on growth of firm size, age, financial position and probability of encountering financing obstacles. I find that my indicator of financing obstacles has a significantly negative effect on firm growth and that financial position matters. In effect, while evidence of the positive role of cash flow on firm growth is unambiguous, results on leverage and debt burden are less clear-cut. In addition, LPE is clearly rejected in three out of the five countries under analysis.

The rest of the paper is organized as follows: after reviewing the existing literature in section 2, I present the datasets and summary statistics in section 3. Section 4 states the steps of the analysis and the empirical model, while in section 5 I discuss the estimation results. Section 6 concludes.

2. Review of Literature

As reviewed by Hart (2001), there is a vast literature on the theories of firm growth. In particular, we can distinguish between a stochastic and a deterministic approach to explain the determinants of firm size. The former argues that in a world with no differences ex ante in profits, size and market power across firms, all changes in size are due to chance. The latter assumes, on the contrary, that growth rate of firms differs because of observable industry and firm specific characteristics.

This paper draws from both approaches to investigate the relationship between financing obstacles and firm growth. With respect to the stochastic approach, I relate to the so called Law of

[1] Small and medium-sized companies represent 99.8 % of all EU-27 enterprises in 2005, employing about 67% of the workforce and generating more than half (57.6%) of its value added (Eurostat SBS, 2005).

Proportionate Effects. Put forward by Gibrat in 1931[2], LPE states that factors that influence firm growth, such as growth of demand, innovation, etc., are distributed across firms in a manner which cannot be predicted from information about firm's current size or its previous growth performance. In the past decades, LPE has been extensively tested for many different countries with mixed empirical results.[3] In effect, it comes out that LPE may hold in particular points in time, for some sectors and/or size classes, but evidence of faster growth of smaller firms suggests that size is often linked to some systematic factors.[4] Age also seems to play a role, for instance because it implies learning (Jovanovich, 1982). Evans (1987a and 1987b) and Dunne, Roberts and Samuelson (1988 and 1989) investigate both size and age effects on growth and find two statistical regularities in their analyses. First, firms' probability of surviving is increasing in size, but, conditional on survival, small firms grow faster.[5] Second, given size, young firms grow faster, but they have a smaller probability of survival.

LPE test is also complicated by two econometric issues. The first concerns the heteroskedasticity arising if the Law is not confirmed, i.e. if small firms grow faster than their larger counterparts, the variance of growth should tend to decrease with size. The second issue was put forward by Chesher (1979) and relates to the inconsistency of ordinary least squares estimators if growth is serially correlated. In the present paper both issues are controlled for.

More recently, a number of theoretical papers explain the departure from the LPE in terms of financing constraints. Cooley and Quadrini (2001) show how a combination of persistent shocks and financial frictions can account for the simultaneous dependence of firm dynamics on size and age. Cabral and Mata (2003) explain the empirical right-skewed firm size distribution with the fact that firms cease to be financially constrained. The authors develop a two period-model of a competitive industry. In the first period the firm may be financially constrained, thus size is the minimum between the optimal size and the size affordable by the entrepreneur; in the second, when the firm is no longer affected by financing constraints, size is at its optimal level. In addition, both Albuquerque and Hopenhayn (2004), who study lending and firm dynamics in a model with limited enforcement, and Clementi and Hopenhayn (2006), who model the relationship between borrower

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[2] Gibrat observed that the size of firms followed the lognormal distribution very closely, from which he concluded that the firms' rate of growth ought to be a random process.

[3] Sutton (1997) provides a review of the theoretical and empirical literature. Among others, see also Mansfield (1962), Hall (1987), Evans (1987a, 1987b) and Goddard, McKillop and Wilson (2002) for USA, Hart and Oulton (1996), Kumar (1985) and Dunne and Hughes (1994) for UK, Goddard, Wilson and Blandon (2002) for Japan, Mata (1994) and Oliveira and Fortunato (2006a) for Portugal, Wagner (1992) and Harhoff, Stahl, Woywode (1998) for Germany, Solinas (1995) and Lotti, Santarelli and Vivarelli (2003) for Italy. Tschoegl (1983), instead, performs a multi-national study.

[4] For instance, government small business policies or the need to reach the minimum efficient scale might explain faster growth of smaller firms.

[5] This result might be affected by a sample selection bias, i.e. as slow growing firms are more likely to exit, small fast growing firms may be over-represented. Lotti, Santarelli and Vivarelli (2003) offer a survey of papers addressing this issue and providing evidence of small firms growing faster.

and lender in the asymmetric information framework, reach very similar conclusions for firm dynamics. In particular, their models are consistent with the empirical findings that as age and size increase, mean and variance of growth decrease, and firm survival increases.

From a purely deterministic point of view, the impact of financing constraints on the real activity of firms is a well known issue, as reviewed by Schiantarelli (1996), Hubbard (1998) and Stein (2003). The main idea is that imperfections in capital markets produce a wedge between the cost of internal and external finance. In particular, asymmetric information between lender and borrower is the main source of this wedge (Meyers and Majluf, 1984). Nevertheless, both theory and empirical evidence focus on the effect of financing constraints on firms' investment decisions, while fewer papers concentrate directly on firm growth. Carpenter and Petersen (2002) address the issue using a panel of small manufacturing US enterprises. They find that the growth of most firms in their sample is constrained by internal finance. Wagenvoort (2003) replicates the model for Europe, adding to the empirical analysis the impact of leverage and firm size, and finds that growth-cash flow sensitivities are decreasing in firm size. Oliveira and Fortunato (2006b) provide evidence that, in Portugal, smaller and younger firms have higher growth-cash flow sensitivities. Applying the same method used here for Belgian and Slovenian firms, Hutchinson and Xavier (2006) find that young firms and firms with long-term debt are most constrained and that micro and SMEs can face great difficulties in accessing external sources of finance. Fagiolo and Luzzi (2006) show on Italian data that the stronger liquidity constraints, the more size negatively affects firm growth.

Overall, the body of this literature implies the need for an a priori classification[6] between financially constrained and unconstrained firms in order to check if the sensitivity of investment/growth to cash flow is higher for constrained than for unconstrained firms.[7] I depart from this debate by making use of survey data to obtain a direct measure of financing obstacles. In this respect, I follow the approach of Beck, Demirgüç-Kunt and Maksimovic (2005) and Beck, Demirgüç-Kunt, Laeven and Maksimovic (2006) that exploit the firm-level information contained in the World Business Environment Survey (WBES) to investigate the effect of financial, legal, and corruption problems on firms' growth rates. Survey data are also used, for instance, by Becchetti and Trovato (2002). They test Gibrat's Law on different waves of a survey on Italian manufacturing

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[6] The splitting criteria focus on firms characteristics that are related to information costs. For instance, small and young firms should face more binding financing obstacles due to the more severe information asymmetries their creditworthiness analysis involves (Devereux and Schiantarelli, 1990; Gilchrist and Himmelberg, 1995). Foreign owned firms and firms belonging to a group (*keiretsu* in Hoshi, Kashyap and Scharfstein, 1991) should suffer less from financing constraints, as they have alternative source of finance. An investment grade rating for corporate bonds also reduces financing constraints (Whited, 1992).

[7] Although many researchers argue that the correlation is due to financing constraints (see the seminal paper by Fazzari, Hubbard and Petersen, 1988 and 2000), others say that cash flow is simply a proxy for investment opportunities (Kaplan and Zingales, 1997a, 1997b and 2000).

firms. They include in the regression a dummy variable which takes value one if the firm reports to be credit constrained. Their analysis rejects LPE and shows that the inclusion of variables measuring the availability of external finance (subsidies, leverage and financing constraints) significantly affects firm growth.

Additionally, I complement the survey data with information on firms' financial position using balance sheet information. Indeed, it is possible to exploit the survey based measure of financing obstacles to investigate directly the relationship between financing constraints and growth, without the need of splitting the sample according to any arbitrary a priori classification.

This paper also complements the literature about financial distress and corporate performance. Among others, Opler and Titman (2004) find that firms with high leverage are more likely to experience performance losses in industry downturns than other firms. Similarly, Bernanke, Gertler and Gilchrist (1996) observe that high leverage reduces the firms' ability to growth through a liquidity effect. In particular, the economy is characterized by a *financial accelerator*. This implies that during recessions borrowers facing high agency costs should receive a relatively lower share of credit, and hence account for a proportionally greater part of the decline in economic activity. By contrast, Lang, Ofek and Stulz (1996) recognize that the relationship between financial distress and firm growth and performance may be sometimes ambiguous. On the one hand, leverage does not reduce growth for firms known to have good investment opportunities; on the other hand, leverage is negatively related to growth for firms whose growth opportunities are either not recognized by capital markets or are not sufficiently valuable to overcome the effects of their debt overhang. In this study, I check the impact of leverage on firm growth, and the role of debt burden, which also measures the degree of financial pressure faced by firms.[8]

Finally, this paper is also linked to the finance-growth literature. A large amount of research provides evidence that financial development has a significantly positive effect on economic growth.[9] The literature has recently been moving from purely cross-country based analysis to a more micro oriented approach, as a way to alleviate some of the limitation of the cross-country analysis, such as reverse causality and multi-collinearity. Seminal papers, in this respect, are Rajan and Zingales (1998) and Demirgüç-Kunt and Maksimovic (1998) based on industry and firm-level data respectively. These papers assume that a well-developed financial system removes or reduces the barriers to external financing for firms. The former argues that industries that are more dependent on external financing should do better in countries with better financial systems.

[8] See Nickell and Nicolitsas (1999), Hernando and Martínez-Carrascal (2008) and Martínez-Carrascal and Ferrando (2008).

[9] See Wachtel (2003), Levine (2005) and Papaioannu (2007) for comprehensive surveys of this literature, showing the development from country level studies to studies that began to exploit industry and firm level data.

Similarly, the latter claims that the proportion of firms that grow rapidly enough to require external financing is related to the development of the financial sector. However, only recently the availability of large firm level panel dataset is permitting to investigate the issue of the relationship between firm growth and the availability of finance. I contribute to this line of research focusing on more homogeneous countries (such as countries in the euro area). Guiso, Jappelli, Padula and Pagano (2004) and Ferrando, Köhler-Ulbrich and Pál (2007) focus on eurozone countries and find some evidence supporting the hypothesis that the lack of financial development constrains more severely the growth of SMEs, which tend also to be more financially constrained than large firms. Aghion, Fally and Scarpetta (2007), using harmonized firm-level data on entry and post-entry growth in 16 countries, find that finance matters most for the entry of small firms, especially in sectors that are more dependent upon external finance, and that financial development improves post-entry growth of firms. Inklaar and Koetter (2008), instead, exploit firm-level information to measure the dependence of industries on external finance and the efficiency of financial intermediaries within the EU-25. They find that the relative efficiency of banks in providing financial services is an important dimension of financial development. The difference with respect to these studies is that I measure directly the probability of having financing obstacles.

3. Data and Summary Statistics

Data come from two sources, WBES and AMADEUS, which are respectively a firm-level survey about constraints to firm growth and performance and a panel dataset collecting balance sheet information. The aim of the paper is to exploit the survey data advantages to overcome the balance sheet data shortcomings and vice versa. Accordingly, I incorporate both data sources to analyze the impact of the financial position of firms on their growth.

3.1 Measuring financing obstacles using survey data (WBES)

My measure of financing obstacles is based on the information derived from the World Business Environment Survey (WBES), which was carried out by the World Bank Group between 1999-2000 to identify obstacles to firm performance and growth around the world. In the questionnaire, the respondents are required to base their answers on the "perception and experience of doing business" in their country.[10] Financial figures, instead, are based on estimation by the respondent over the previous one or three years. The time horizon is specified in the paper each time a new variable is introduced. Qualitative variables other than obstacles to growth, like size, refer to the time the questionnaire was administrated.

[10] Data and documentation are available at http://info.worldbank.org/governance/wbes/index.html#wbes.

A fundamental property of WBES is that data are at the firm-level. In particular, WBES database is size-stratified and has excellent coverage of small and medium-sized firms, where small firms are those with 5–50 employees. Medium-sized firms are those that employ 51–500 employees, and large firms are those with more than 500 employees.[11] Sectors are defined at a broad level and they include manufacturing, services, agriculture and construction. The survey was administered in such a way that the sectoral composition in terms of manufacturing (including agro-processing) versus services (including commerce) is determined by relative contribution to GDP, subject to a 15% minimum for each category.[12]

I use information over about 500 firms across five euro area countries: France, Germany, Italy, Spain and Portugal.[13] I exclude firms in the agriculture sector or whose government owned share is above 50%, thus I end up with 482 firms. Around 80% of the sample consists in small and medium enterprises (SMEs), 20% in large firms, and 11% are young firms. About 30% are in manufacturing, 64% in services, and the residual 6.5% in the construction industry. Only 11% of the firms are listed and even less are owned by business groups, while 27% are foreign owned (see Table 3.1 that also shows the composition of the sample across countries).

[11] Usually cross-country studies of corporate finance focus mainly on large, listed corporations. However, firms with less than 5 employees, i.e. micro firms, are not surveyed in the WBES. The number of employee itself is not available.

[12] Other criteria for the survey administration at country level are that at least 15% of firms should be foreign owned and at least 15% should export some significant share of their output.

[13] The WBES has been totally or partially exploited by a number of papers for different purposes. Beck, Demirgüç-Kunt and Maksimovic (2004, 2005) investigate respectively the effect of the banking market structure on the access of firms to bank finance over 74 countries, and financial and legal constraints to firm growth over 54. Beck, Demirgüç-Kunt and Levine (2006) analyze, using data on 37 economies, the impact of different bank supervisory policies on firms' financing obstacles. Beck, Demirgüç-Kunt, Laeven and Maksimovic (2006), instead, exploit the whole dataset of 80 countries. The latter paper is the most related to the present research, since it explores the determinants of financing obstacles.

Table 3.1 Country-level sample composition

	France	Germany	Italy	Portugal	Spain	Total
N	97	96	94	97	98	482
Small	36.1%	26.0%	24.5%	39.2%	32.7%	31.7%
Medium	42.3%	60.4%	51.1%	37.1%	56.1%	49.4%
Large	21.6%	13.5%	24.5%	23.7%	11.2%	18.9%
Young	19.8%	11.6%	10.6%	4.2%	11.6%	11.4%
Manufacturing	37.1%	20.8%	27.3%	25.8%	35.7%	29.4%
Services	58.8%	64.6%	68.2%	70.1%	59.2%	64.1%
Construction	4.1%	14.6%	4.5%	4.1%	5.1%	6.5%
Listed	12.5%	4.2%	16.0%	20.6%	0.0%	10.7%
Group	14.4%	10.5%	0.0%	5.3%	9.8%	8.0%
Foreign	22.9%	30.2%	29.3%	25.5%	28.9%	27.3%

Note: The table reports the country-level sample composition in the different countries. Small firms employ 5-50 employees, medium firms 51-500 and large firms over 500 employees. Young is a dummy variable which takes value 1 if the firm has less than 6 years. Listed firms are firms quoted on a stock exchange. Group indicates firms controlled by a company group. Foreign indicates firms with foreign ownership. Source: WBES and own calculations.

The survey includes both specific and generic questions about financing obstacles. The questions are formulated as “can you tell me how problematic is … for the operation and growth of your business?”. For all these questions the answers, summarized in Table 3.2, ranges from 1, no obstacle, to 4, major obstacle.

Table 3.2 Summary statistics

	N	Mean	SD	Median	p75
General financing obstacle	472	2.25	1.11	2	3
Collateral requirements	453	2.11	1.05	2	3
High interest rates	458	2.44	1.02	2	3
Access to long-term loans	445	1.83	1.01	1	2
Bank paperwork/bureaucracy	463	2.35	1.01	2	3
Need special connection	453	2.01	0.99	2	3
Banks’ lack of money to lend	444	1.66	0.99	1	2
Access to foreign banks	403	1.53	0.82	1	2
Access to non-bank equity	396	1.67	0.92	1	2
Access to export finance	353	1.61	0.90	1	2
Access to leasing finance	422	1.88	0.93	2	3
Inadequate credit/financial information	435	1.97	1.03	2	3
Corruption of bank officials	421	1.34	0.69	1	1

Note: The table reports summary statistics for the variables representing financial obstacles. They are the answers to the question: “can you tell me how problematic is … for the operation and growth of your business?” Answers vary between 1 (no obstacle), 2 (minor obstacle), 3 (moderate obstacle), and 4 (major obstacle). Source: WBES and own calculations.

Researchers are usually worried about the possibility of bias in data based on self-reporting by firms. The WEBS is less prone to standard arguments against surveys because its purpose is to evaluate the business environment, not firm performance. As pointed out by Beck, Demirgüç-Kunt, and Maksimovic (2005), firms were asked just few specific questions about their performance *at the end* of the interview, and the majority of the questions refer to business conditions and government policies. This implies that there is not a big extent in justifying performance when answering the earlier questions about the business environment. Moreover, if an unsuccessful not financially constrained firm wants to justify its poor performance, it is likely that the respondent would find other, more immediate excuses than financing obstacles. However, the authors do not consider that self-reporting bias might still arise in reporting the severity of the obstacle. A firm may exaggerate the severity of its financing obstacle, and rate it as "major" while in effect it is only "moderate". This could bias the ordinal nature of the answers. Thus, I consider a financing obstacle as binding if rated as moderate or major (rating 3 or 4), and not binding otherwise (rating 1 or 2).[14] It remains still possible that while firms report financing obstacles, they are actually not constrained by them. In addition, the formulation of the question might imply that firms report obstacles because they are experiencing low growth. Following Beck, Demirgüç-Kunt, Laeven and Maksimovic (2006), in order to distinguish the self-reported constraints from actual constraints, I refer to the former as obstacles. Differently from them I do not focus directly on the general financing obstacle measure but on a specific indicator.[15] An alternative would be to build an index considering all the specific financing obstacles, or at least the most frequent (high interest rates, collateral requirements and paperwork[16]). The risk would be a further reduction of the already small sample size, as we should exclude firms not answering to all the relevant questions. However, this might represent an interesting way to extend the analysis, as for some firms some obstacles may be more important than others.

In order to select a measure of financing obstacle, I performed a preliminary analysis to measure the contribution of each specific financing obstacles to the more general measure, the

[14] Overall, 12% of the firms in our sample report collateral as a major obstacle, 25% rate it as a moderate obstacle, 25% respond that collateral is a minor obstacle, while 38% report that it is not an obstacle to firm growth. Beck, Demirguc-Kunt and Levinel (2006) also divide the responses in two categories to use a comparatively balanced distribution of responses, and to reduce the possible influence of outliers. Alternative rules would be to consider financing obstacles binding if rated 2-4 or if rated 4 only. I did not choose the first rule because it is too prone to the standard argument against survey data. Conversely, I did not choose the second rule to avoid to be over conservative. In addition, both rules do not lead to a balanced distribution of responses.

[15] At the earliest stage of the work, I was suggested to use a specific factor instead of the General financing obstacle, as this latter was considered to be too general and then it would have biased upward my measure of financing obstacles.

[16] See Table A.1 in the appendix for summary statistics.

result is that collateral is the major determinants of the general financing obstacle.[17] Thus, I focus on the collateral requirements indicator, and I call it *FinObst*. Indeed, the importance of collateral requirements is well known among scholars. Financial market imperfections are likely to be especially binding on enterprises that lack collateral, thus limiting their financing opportunities and leading to slower growth. Firms' access to debt depending on collateral has been modeled, among the others, by Bernanke, Gertler, and Gilchrist (1996). More recently, Clementi and Hopenhayn (2006) base optimal lending contract design on the relative value of collateral and projects to be financed. Berger and Udell (2006) argue that lending technologies are the key conduit through which government policies and national financial structures affect credit availability. In this framework, collateral arises in many different technologies as a crucial point.[18]

Table 3.3 shows the composition of FinObst across the sample according to the different countries. In particular, Germany is the country with highest percentage of firms reporting financing obstacles. Italy follows with 51.8%, then Spain and France with about 30% of firms. In Portugal, only 13% of firms in the sample report financing obstacles.[19] About 37% of the firms report financing obstacles. Around 88% of those are SMEs (38% small and 49% medium), 15% have less than 6 years, only 8% belong to a group, just a few more are listed, and 31% are foreign owned. About 34% are in manufacturing, 55% in services, and 11% in the construction industry.

[17] Since the variables are dichotomous, in addition to simple regression analysis I specified the model either as a probit or as a logit. I controlled for country effects, for sector effects and for country and sector effects. The result is that collateral is the major determinant of the general financing obstacle. Table A.2 in the Appendix reports the pairwise Pearson correlation coefficients. Correlations are significant at the 5% level both to the standard and to the bootstrap (with 5,000 resampling) significance tests.

[18] In any case, given that high interest rates could be a good proxy for financing obstacles, I performed the econometric analysis also using this indicator. However, collateral requirements confirmed to be most informative.

[19] When comparing the country results, it is worth to remember the caveat included in the User agreement for WBES Dataset stating that "Given inherent error margins associated with any single survey results, it is inappropriate to use the results from this survey for precise country rankings in any particular dimension of the investment climate or governance".

Table 3.3 Financing obstacles across countries

	France	Germany	Italy	Portugal	Spain	Total
Small	50.0%	31.0%	29.5%	58.3%	48.3%	38.46%
Medium	26.9%	62.1%	50.0%	41.7%	44.8%	49.1%
Large	23.1%	6.9%	20.5%	0.0%	6.9%	12.4%
Young	19.2%	13.8%	11.4%	16.7%	17.2%	14.97%
Manufacturing	38.5%	25.9%	34.1%	16.7%	51.7%	33.93%
Services	53.8%	56.9%	56.8%	66.7%	41.4%	54.76%
Construction	7.7%	17.2%	6.8%	16.7%	6.9%	11.31%
Listed	3.8%	1.7%	11.4%	0.0%	0.0%	4.24%
Group	15.4%	10.3%	0.0%	0.0%	6.9%	7.23%
Foreign	7.7%	32.8%	20.5%	8.3%	20.7%	21.89%
Total	30.2%	61.1%	51.8%	13.0%	30.5%	37.3%

Note: The table reports the country-level sample composition for firms reporting financing obstacles. Small firms employ 5-50 employees, medium firms 51-500 and large firms over 500 employees. Young is a dummy variable which takes value 1 if the firm has less than 6 years. Listed firms are firms quoted on a stock exchange. Group indicates firms controlled by a company group. Foreign indicates firms with foreign ownership. Source: WBES and own calculations.

In order to gain some intuition on the relationship between financing obstacles and firm growth, Table 3.4 reports summary statistics of two common measures for the growth rate of firms. These are the percentage change in firm sales/number of employees over the past three years.[20] Both measures exhibit, on average, higher percentage rates of growth for firms reporting no financing obstacles. However, the intergroup difference in means is significantly different from zero for the change in sales but not for the change in the number of employees.

Table 3.4 Firms' growth rate and financing obstacles

Growth of sales	N	Mean	SD	Median	Min	Max
Yes	147	9.48	18.40	10	-50	100
No	228	13.64	20.58	10	-20	100
Total	375	12.01	19.84	10	-50	100
Growth of employees	N	Mean	SD	Median	Min	Max
Yes	154	6.84	26.23	0	-100	100
No	252	8.09	21.18	0	-50	100
Total	406	7.62	23.20	0	-100	100

Note: Growth of sales and growth of employees are directly reported by the respondents as the percentage change in firm sales/number of employees over the past three years. FinObst is a dummy variable taking value one (yes) if collateral requirements are a moderate-major obstacle and zero (no) otherwise. Source: WBES and own calculations.

[20] Later on, I will measure the growth rate of firms in terms of changes in total assets. Unfortunately, the WBES does not include this information. For the same period and countries the growth of sales in Amadeus is about 15%. It is not possible to compare the growth of employees, instead, as a large number of firms in the Amadeus sample do not report this information.

This simple evidence suggests the existence of a negative relationship between financing difficulties and firm sales growth. This is also confirmed by the results obtained in Beck, Demirgüç-Kunt, and Maksimovic (2005). After controlling for firm characteristics and country development, they find that (different proxies for) financing obstacles have a negative and sufficiently large effect on growth.[21]

3.2 Balance sheet data: AMADEUS database

Balance sheet information is derived from the AMADEUS[22] Bureau van Dijk database. This is a comprehensive, pan-European database containing financial information on over 10 million public and private companies. Consistently with the WBES sample, I select non-financial corporations in France, Germany, Italy, Spain and Portugal.[23]

The original dataset contains financial information for the period 1990-2005; I drop the first three years because of poor coverage[24] and I loose another year of observations to compute variables as first differences of the balance sheet items. I keep only firms with at least six consecutive years of observations. Moreover, for holding firms I exploit the consolidated annual accounts, whenever available, as these are considered to be most suitable for providing information about the financial situation of a company with subsidiaries. This implies that mergers and acquisitions of lines of business belonging to any parent firm may show up in the consolidated budget of the parent firm. Since I do not want the results to be affected by growth in assets derived from merger, acquisitions, or disinvestment activities, but rather by growth determined by the activity of the firm, firms that exhibit an annual percentage growth rate of total assets larger than one in absolute value are deleted from the sample.

The sample selection leaves us an unbalanced panel of 155,440 firms and 1,018,027 observations. In spite of the huge number of observation, the coverage differs across countries.[25] Nevertheless, apart from Germany, the percentage of SMEs is very high: over 90% for France, Italy and Portugal, and about 85% for Spain. Another advantage of AMADEUS is the wide incidence of

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[21] Additional results, based on the WBES, on firms' access to finance and growth are in Demirgüç-Kunt, Beck and Honohan (2008).
[22] Analyse major databases from European sources.
[23] For the same reason, I exclude firms in the agriculture, forestry, fishing and mining sectors. I also leave out micro firms. Recall that firms with less than 5 employees are not surveyed in the WBES. Moreover, I use end of year data.
[24] For the same reason I drop an additional year in France, where the final sample covers the years 1995-2005.
[25] The different coverage is a shortcoming of the AMADEUS database.

non listed firms, these are 99.5% of the sample, as shown in Table 3.5. Young firms, i.e. firms with less than 6 years, are instead only 6.3% of the sample.[26]

Table 3.5 Country- level sample composition

	France	Germany	Italy	Spain	Portugal	Total
# obs.	318,802	9,127	305,400	360,496	24,202	1,018,027
# firms	68,930	1,172	34,582	42,807	7,949	155,440
Small	64.7%	8.9%	66.0%	74.6%	48.9%	67.7%
Medium	26.7%	23.9%	29.5%	21.2%	36.1%	25.8%
Large	8.6%	67.2%	4.5%	4.2%	15.0%	6.5%
Young	6.8%	9.8%	3.4%	8.3%	4.4%	6.3%
Manifacturing	28.8%	20.2%	52.3%	36.8%	43.5%	10.2%
Services	22.4%	39.6%	9.5%	15.9%	9.1%	39.0%
Construction	9.8%	4.6%	7.4%	13.0%	10.4%	16.0%
Other setors	39.0%	35.6%	30.8%	34.4%	37.0%	34.8%
Listed	0.7%	17.1%	0.2%	0.3%	1.7%	0.5%

Note: The table breaks down the sample composition at country level. Micro firms and firms with less than six consecutive years of information are excluded. Young is a dummy variable which takes value 1 if the firm has less than 6 years. Listed firms are firms quoted on a stock exchange. Source: AMADEUS Bureau van Djik Electronic Publishing and own calculations.

I apply, as size class definition, the classification scheme adopted by the European Commission that relies on the number of employees and on a joint condition on either total assets or turnover. In addition, following Martìnez-Carrascal and Ferrando (2008), the thresholds for assets and turnover which define different size classes are adjusted over time, using the gross value added deflator.[27]

As in Carpenter and Petersen (2002), I measure firm growth as the difference between the natural logarithm of real total assets for two subsequent years.[28] Figure 3.1 shows the pattern of the median growth across countries. The median firm' growth rate showed an increasing trend in the

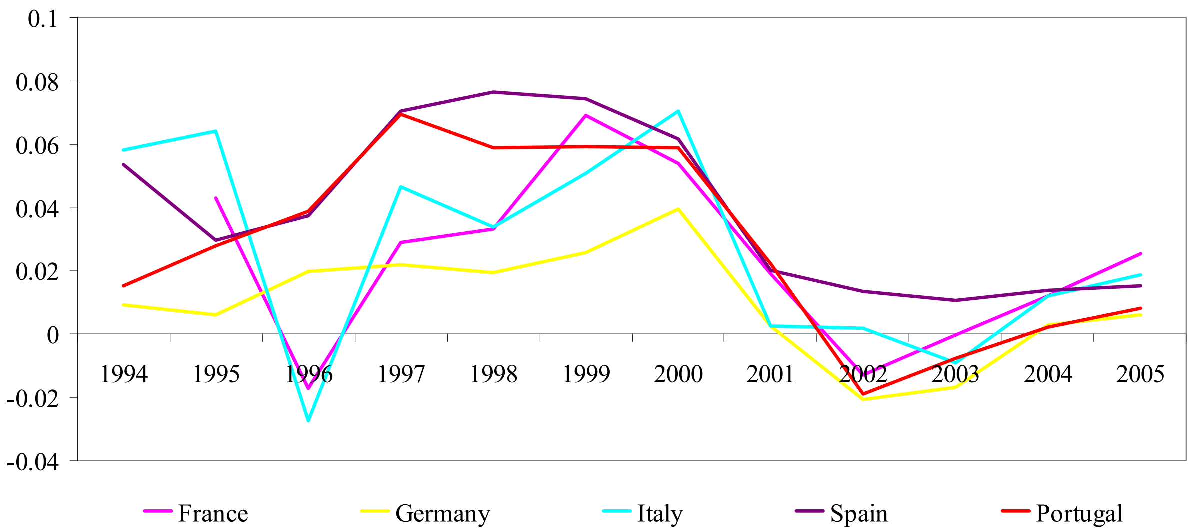
[26] Age is measured from the time the firm was born. It might be biased because of M&A operations making less reliable the interpretation of the year of incorporation. However, in this paper age is taken into account through a dummy variable identifying young firms, and young firms are less likely to suffer from this bias.

[27] This classification differs somewhat from the one used in the WBES, where classes are defined only in terms of employees. The closest criteria are for small firms. In the growth analysis size is measured with the logarithm of total assets in real terms (as in Carpenter and Petersen, 2002). Hence, the difference in size class definitions might be relevant, through the use of a dummy for small firms, only in the estimation of the determinants of financing obstacles. The assumption is that the difference in size criteria should not strongly affect results. To avoid such a bias, one should build in AMADEUS a dummy for small firms only based on the number of employees. However, this choice would strongly bias the analysis: deleting from the sample the firms not reporting the number of employees would shorten the time series dimension of the panel and bias the sample towards large firms.

[28] It can be argued that annual growth rates are noisy, and that measurement over longer periods might yield more meaningful growth data. However, aggregating or averaging growth over time would result in a too low number of observations per company. Therefore, I use annual growth rates and I include lagged annual growth rates in the estimation (see also Goddard, Wilson and Blandon,2002).

second half of the nineties and peaked, in the context of strong economic growth, around 1998-2000. The growth rate declined afterwards, in an environment of weaker economic activity. The convergence of firms' growth rate is clear, especially after the introduction of the single currency in 2000. This might be partly linked to more synchronized cycles across countries after the start of the Stage Three of Economic and Monetary Union.

Figure 3.1. Median firms' growth rate across countries



Note: The figure displays median annual growth rates of firms. Firm's growth rate is measured as the difference between the natural logarithm of real total assets for two subsequent years. Source: AMADEUS Bureau van Djik Electronic Publishing and own calculations.

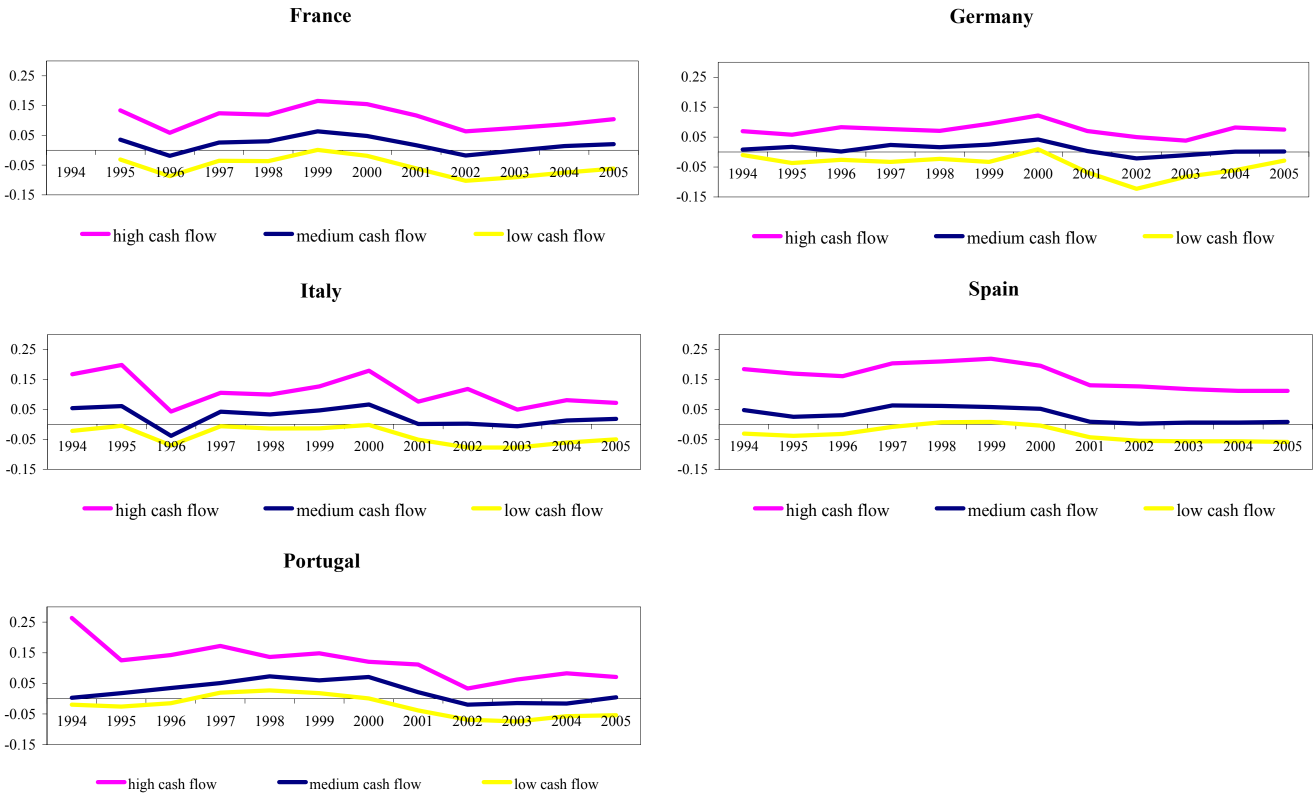
To gain some intuition on the relationship between firm growth and its financial position, I select three financial indicators: cash flow, indebtedness and debt burden. The first indicator is computed as the sum of the per-period profit/losses and depreciation, scaled on the total assets at the beginning of the year. The second is the ratio between total debt and total assets, thus it is a measure of leverage. The third one measures financial pressure as the ratio between interest paid and EBITDA. [29]

As a preliminary way to analyze the relationship between these indicators and firm growth, I split the sample in three groups representing respectively high, medium, and low "financial position". The groupings are defined with respect to the percentile in which firms fall: above the 90^{th} percentile (high), between the 45^{th} and the 55^{th} percentile (medium), below the 10^{th} percentile (low). Finally, I compute the median growth rate of firms belonging to each group. The following figures display the output of this computation across countries.

[29] For Portugal I could not compute debt burden because very few firms report data on interests paid.

Figure 3.2 depicts the median growth rate for firms with different cash flow levels. There is a clear positive relationship between cash flow and growth for all the countries, suggesting that firm growth might depend on the availability of internal finance. Indeed, the higher the profits generated by firms, the higher their growth rate.[30]

Figure 3.2 Cash flow and firm growth



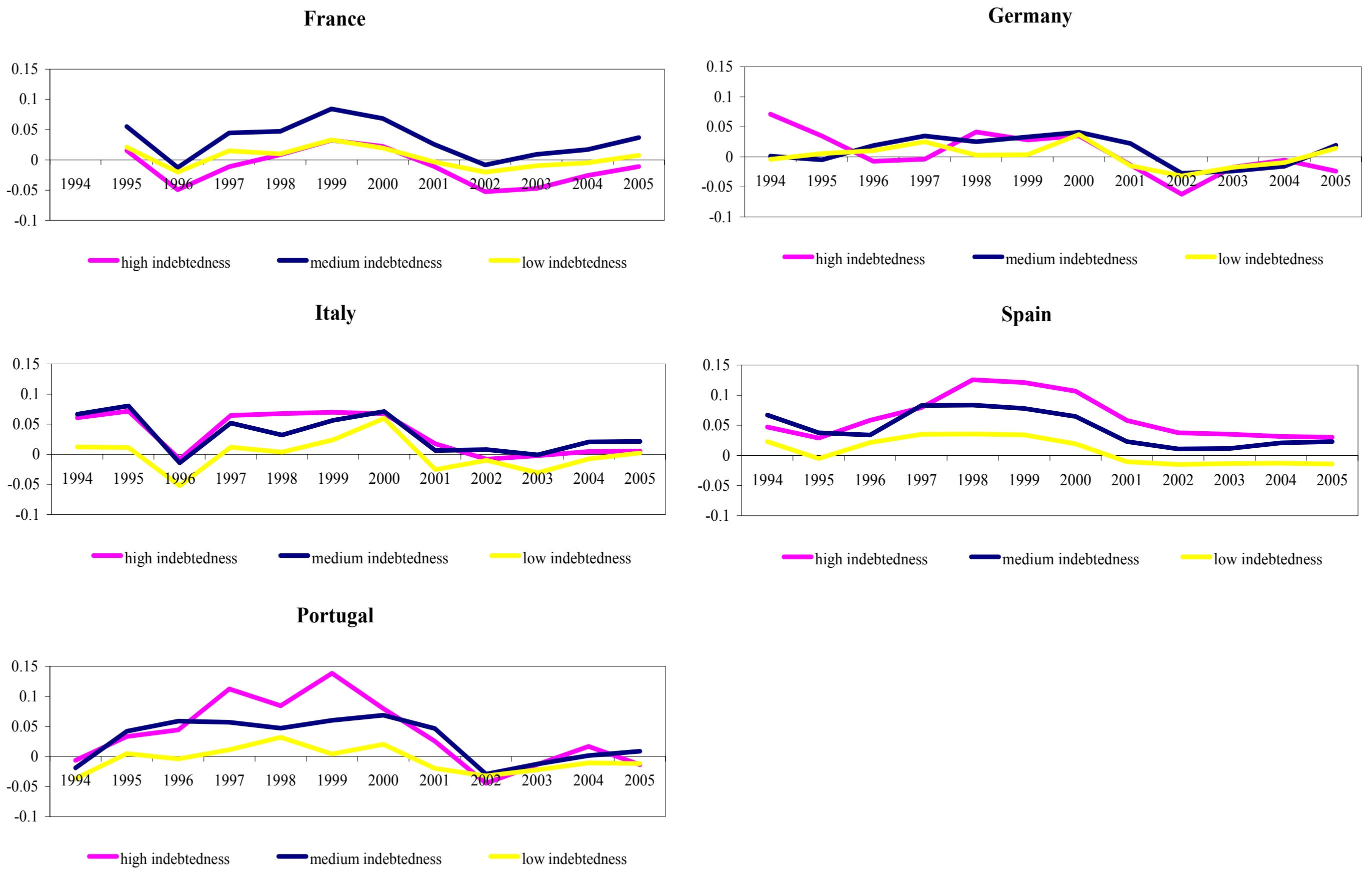
Note: Firms grouping is defined with respect to the percentile in which firms fall: above the 90th percentile (high cash flow), between the 45th and the 55th percentile (medium cash flow), below the 10th percentile (low cash flow).Cash flow is measured as the sum of profit/losses and depreciation in a given year, scaled on the total assets at the beginning of the period. Source: AMADEUS Bureau van Djik Electronic Publishing and own calculations.

Figure 3.3 confirms the more blurred relationship between leverage and growth. Indeed, while in France highly leveraged firms show lower growth rates than firms with medium or low indebtedness levels, in Spain (and even Portugal) companies which are most indebted are those presenting on average higher growth rates. The absence of a clear relationship between both variables might be the consequence of two opposite effects. On the one hand, highly leveraged firms may experience difficulties in raising additional external funds to expand their business,

[30] An analogous relationship, for which the chart is not displayed, exists between growth and growth opportunities, the latter are measured as the growth rate of sales in real terms.

while, on the other hand, firms with higher indebtedness level might be those which have been more successful in attracting external funds to take advantage of their growth opportunities.[31]

Figure 3.3 Indebtedness and firm growth



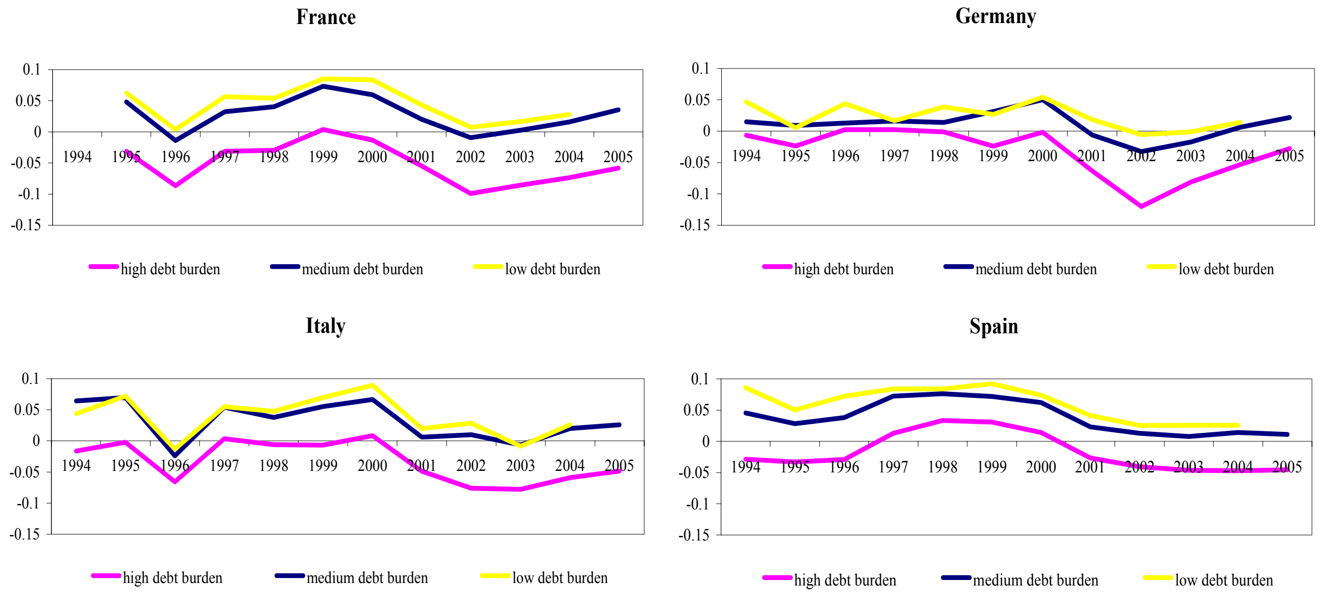
Note: Firms grouping is defined with respect to the percentile in which firms fall: above the 90th percentile (high indebtedness), between the 45th and the 55th percentile (medium indebtedness), below the 10th percentile (low indebtedness). Indebtedness is the ratio between total debt and total assets. Source: AMADEUS Bureau van Djik Electronic Publishing and own calculations.

Another indicator of financial pressure, debt burden, provides a clearer interpretation: firms facing high debt burden grow less. Interestingly, the evidence in Figure 3.4 indicates that firms characterized by medium and low level of debt burden show no marked differences in their growth rates, which are, at the same time, higher than those observed for firms facing highest degree of

[31] A simple regression analysis seems to point in this direction: I find a positive relationship between growth opportunities and the increase of debt. On the other hand, the positive link between these two variables tends to be stronger only with moderate levels of indebtedness (probably reflecting that highly leveraged firms are likely to have more difficulties in raising additional external funds).

financial pressure according to this indicator. This might point to the existence of a non-linear impact of financial position on growth.[32]

Figure 3.4 Debt burden and firm growth



Note: Firms grouping is defined with respect to the percentile in which firms fall: above the 90th percentile (high debt burden), between the 45th and the 55th percentile (medium debt burden), below the 10th percentile (low debt burden). Debt burden is the ratio between interest paid and EBITDA. No chart is presented for Portugal because for most of the companies the AMADEUS database does not include information on the debt burden. Source: AMADEUS Bureau van Djik Electronic Publishing and own calculations.

Overall, the graphs suggest that firm' growth rate is affected by financial position, especially when the latter is proxied by cash flow or debt burden. The evidence on indebtedness is not clear-cut. However, this simple bivariate analysis does not control for other variables that might affect growth. Hence, to extract more conclusive evidence on the impact of financial position on firms growth, I perform an econometric analysis, which allows controlling for other potential determinants of firms growth.

4. The model: a three step approach

As showed before, there are different strands of literature investigating the relationship between financing constraints and firm growth. This literature, however, mainly relies on indirect measures of financing constraints based on balance sheet data. In contrast, I exploit the information

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[32] See Hernando and Martínez-Carrascal (2008), who offer evidence of a non-linear impact of financial position on investment.

from the WBES survey to obtain a direct indicator of financing obstacles faced by firms and I complement the analysis with the richness of balance sheet data in the AMADEUS database.

The analysis consists in three steps. First, in the WBES I estimate the determinants of financing obstacles, proxied by FinObst, to work out an indicator of financing obstacles. Second, the estimated coefficients are applied into AMADEUS in order to compute the predicted probability of a firm facing financing obstacles (FO). Finally, the indicator FO is used as a regressor in a dynamic model for firm growth.

In the first step of the analysis, I rely on survey data to analyse which type of firm' characteristics make it more likely for firms to feel the existence of financing obstacles. As in Beck, Demirgüç-Kunt, Laeven and Maksimovic (2006), I assume that the firm's underlying response can be described by the following equation:

$$FinObst_{i,k} = \theta \ \ country_k + \sum_j \phi_j FirmCharacteristics_{i,k} + \varepsilon_{i,k} \qquad (1)$$

where FinObst is the answer reported by firm *i* in country *k*, and FirmCharacteristics is a vector of firm attributes. These attributes include the dummy variables small, young and group. I control for firms' demand by including the natural logarithm of sales. Moreover, I control for industry specific effects through sectoral dummies. Balance sheet information on variables such as indebtedness or debt burden are not available in the survey, hence cannot be included in this first step of the analysis, but will be considered afterwards. Given that the dependent variable is dichotomous, I use a probit model to estimate equation (1). I assume that the disturbance parameter, $\varepsilon_{i,k}$, has normal distribution and use standard maximum likelihood estimation. Since omitted country characteristics might cause error terms to be correlated for firms within countries, I should allow for clustered error terms as in Beck, Demirgüç-Kunt, Laeven and Maksimovic (2006). Differently from them, the paper deals with a sub-sample of WBES with only 5 countries out of 80. Thus I have large clusters, i.e. a small number of clusters with respect to the total sample size. Therefore, I can directly keep into account country effects through the inclusion of country dummies.[33]

[33] Large clusters imply that the intercepts and the slope coefficients can be estimated consistently as the number of observation in each cluster approaches infinity. I end up with the so called cluster dummy variables probit model. This is an example of nonlinear cluster-specific fixed effect (CSFE) model, hence we are assuming that the intercept might be correlated with regressors, which is a more general assumption with repect to random effect models. Moreover, CSFE implies that we cannot use in the model cluster invariant variables, such as GDP, because their effect is not identifiable with respect to the intercept (Cameron and Trivedi, 2005; Wooldridge, 2003). For a survey see Pendergast et al. (1996). Moreover, the results of the estimation of a simple logit model are qualitatively similar to those of the probit model. In fact, we obtain the same marginal impacts as in the probit model.

As a second step, the estimated vector of coefficients, (θ_k, ϕ_j), is used into AMADEUS to compute the linear prediction of FinObst for each firm-year observation in each country.[34] The assumptions are that the coefficients are constant over time and across country. With respect to the former assumption, I control for country fixed effects. The latter assumption is more binding, as the survey has not a time dimension. Indeed, we are assuming that firms feelings have remained the same for the entire AMADEUS sample period. This is undoubtedly a shortcoming of the research, but the WEBS survey is the best data source available for this analysis.[35] Finally, I derive the predicted probability of having financing obstacles, FO. As the equation (1) is estimated using a probit model, FO is simply the cumulative standard normal distribution evaluated at the linear prediction of the model.

The last step consists in the estimation of a model for firm growth. I ground on both the stochastic and the deterministic approaches and choose to test an *augmented* version of LPE. In the univariate case Gibrat's law is usually estimated as:

$$\begin{aligned} growth_{i,t} &= \alpha_i + \delta_t + (\beta - 1) size_{i,t-1} + \mu_{i,t}, \\ \mu_{i,t} &= \rho \mu_{i,t-1} + \varepsilon_{i,t} \end{aligned} \qquad (2)$$

where and α_i and δ_t allow for individual and time effects, respectively. The unobserved time-invariant firm specific effects, α_i, allows for heterogeneity across firms, and ρ captures persistence of chance[36] or serial correlation in the disturbance term $\mu_{i,t}$. Finally, $\varepsilon_{i,t}$, is a random disturbance, assumed to be normal, independent and identically distributed (IID) with $E(\varepsilon_{i,t}) = 0$ and $var(\varepsilon_{i,t}) = \sigma^2_\varepsilon > 0$. According to Tschoegl (1983), departures from LPE arise if $\beta \neq 1$, i.e. size reverts to the mean ($\beta < 1$) or it is explosive ($\beta > 1$); $\rho \neq 0$, i.e. growth is persistent, or the growth rates are heteroskedastic.

Goddard, Wilson and Blandon (2002) rearrange model (2) for the purposes of panel estimation as:

$$growth_{i,t} = \alpha_i (1 - \rho) + \delta_t + \rho growth_{i,t-1} + (\beta_0 - 1) size_{i,t-1} + \eta_{i,t} \qquad (3)$$

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[34] As in the WEBS survey firms are not identifiable, it is not possible to know if they are also incorporated in AMADEUS.

[35] However, as mentioned above, the respondent are required to base their answers on their past experience, therefore it is also possible to interpret the answers in a structural way.

[36] As suggested by Chesher (1979).

where $\eta_{i,t}= \varepsilon_{i,t} + \rho(1-\beta)size_{i,t-2}$, thus under the null hypothesis $\beta = 1$ we have that $\eta_{i,t}= \varepsilon_{i,t}$. I assume an augmented version of (3). For augmented I mean that economic meaning is added to the simple LPE regression, through the inclusion of variables that deterministically affect growth. The final equation is then:

$$growth_{i,t} = \alpha_i(1-\rho) + \delta_t + \rho growth_{i,t-1} + (\beta_0 - 1)size_{i,t-1} + \sum_{j=1}^{k} \beta_j x_{j,i,t-l} + \eta_{i,t} \tag{4}$$

where x is a vector of explicative variables lagged l times. Alternatively, equation (4) can be interpreted as a version of Carpenter and Petersen (2002) model augmented by size and past growth rates. I include in x the dummy young, and one period lagged values for cash flow, leverage, debt burden and FO. The annual growth rate of sales, instead, is introduced as a proxy for growth opportunities. Ideally, I should have included the usual Tobin´s Q measure as a proxy for growth opportunities, but also this variable is importantly affected by measurement errors and in any case it is not possible to construct this variable with this database since most of the firms in the sample are non-quoted. Therefore some authors (for instance Gomes, 2001) suggest using changes in profit or sales.[37] Except the latter and the dummy young, all right-hand side variables are lagged one period to reduce possible endogeneity problems.

I estimate the dynamic model (4) through the GMM-system estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998), which has recently been used to test augmented versions of LPE.[38] As emphasized in Bond, Hoeffler and Temple (2001), this estimation procedure has important advantages over other estimation methods in the context of empirical growth models. Indeed, this estimator controls for the presence of unobserved firm-specific effects – e.g. the efficiency level- that can be correlated with the firms' growth rate and with the explanatory variables and hence it avoids the bias that arises in this context. Likewise, by using instrumental variable methods, the GMM estimator allows to estimate parameters consistently in models that include endogenous right-hand side variables. This fosters the use of a GMM-estimator over simple cross-section regressions or other estimation methods for dynamic panel data.

[37] Lang, Ofek and Stulz (1996) use the growth of sales as a regressor in their growth equation estimation. Nickel and Nicolitsas (1999), Benito and Hernando (2007, 2008) and Hernando and Martinez-Carrascal (2008) use sales growth in the estimation of investment/labor equations as a proxy for demand shocks, which we can argue to be linked to growth opportunities. Wagenwoort (2003), instead, solves the same issue explaining *Q*-values of quoted companies in a different dataset and using the econometric model to obtain *Q*-values of unquoted companies.

[38] See for instance Oliveira and Forunato (2006b) for Portugal, and Hutchinson and Xavier (2006) for Belgium and Slovenia.

In addition, the high persistence of the series that is typically present in empirical growth models favours the use of a GMM-system estimator rather than the GMM first-difference estimator. As discussed in Blundell and Bond (1998), when the time series are highly persistent, the first-difference GMM estimator may be subject to a downward bias. They show that in autoregressive-distributed lag models, first-differences of the variables can be used in level equations as instruments, provided that they are mean stationary, and that dramatic reductions in the bias and gains in precision can be obtained by using these alternative equations.

If the underlying model residuals are white noise, then first-order serial correlation should be expected in the first-differenced residuals for which I present the test of Arellano and Bond (1991), labelled M_1. At the same time, no second order correlation in the first differenced residuals should be observed. I present the test of Arellano and Bond (1991), labelled M_2, to test for this hypothesis, which indicates the key condition for the validity of this method. I also report the results of the Sargan test of overidentifying restrictions as test for instruments validity, although Blundell, Bond and Windmeijer (2000) report Monte-Carlo evidence showing that this test tends to over-reject, especially when the data are persistent and the number of time-series observations large.

5. Firm growth determinants

The summary statistics reported in Table 3.4 suggest that financing obstacles negatively affect growth. Also the descriptive evidence in Figures 3.1-3.3 shows that firms' financial health – especially when proxied by cash flow and debt burden- seems to affect firm growth. In this section I apply the three step analysis to see whether financing obstacles affect growth after controlling for firm's characteristics and firm's financial position.

5.1 Steps 1 and 2: the determinants of financing obstacles

In the first step, I rely on the dummy variables probit model to study the determinant of financing obstacles in our sample of euro area non-financial corporations. The results from the estimation of equation (1) are reported in Table 5.1. Since the goal is to apply the estimated coefficients to a different dataset, I restrict the choice of the independent variables to those included in both datasets: the dummies listed, group, young, and the log of sales. This might constrain the analysis, but, in any case, evidence on previous studies indicates that the variables used here are the most relevant, amongst those included in the WBES survey, in order to predict financing obstacles.[39]

[39] Beck, Demirgüç-Kunt, and Maksimovic (2006), who use a larger set of variables in the WBES, find that age, size and ownership predict financing obstacles better than the other firms' attributes.

Consistently with literature, young firms and, when significant, small firms encounter financing obstacles with a higher probability.[40] Either small size, or alternatively a dummy for listed companies are relevant for explaining this probability, but both variables are never significant at the same time. The dummy group, instead, is never significant. Likewise, firms in the manufacturing and in the construction sector face (or have the feeling of facing) more financing obstacles than those in the service sector. The percentage of correctly classified firms is around 70% in all the specification, the highest figure corresponding to the third one. More specifically, according to this specification, being young increases the probability of facing financing obstacles by 16%.[41] Having higher firm performance in terms of sales, instead, always reduces the probability of feeling constrained: a 1% increase in the growth rate of sales reduces this probability by nearly 4%. Small size increases this probability by about 13%, while being in the manufacturing or in the construction sector increases this probability by 18% and 26%, respectively. These large sectoral differences might be linked to factors such as differences in the level of assets that can be easily used as collateral. Indeed, according to the AMADEUS database, the percentage of tangible assets is higher in the service sector than in the manufacturing sector and, even more dramatically, in the construction sector.

[40] I also estimated the model using log of age instead of the dummy young. I obtained a negative and significant relationship confirming that younger firms suffer more from financing obstacles. In addition, when I allow for a different impact of medium or large companies, both dummies are non-significant.

[41] Marginal impacts are evaluated at the sample mean. Bootstrap analysis with 5,000 random resampling confirms the estimation results.

Table 5.1 Financing Obstacles and firms characteristics

	(1)	(2)	(3)
Small	0.243	0.239	0.327**
	0.17	*0.17*	*0.16*
Young	0.432*	0.496**	0.407*
	0.23	*0.23*	*0.23*
Lnsales	-0.090**	-0.083**	-0.100**
	0.04	*0.04*	*0.04*
Group	0.128		0.077
	0.29		*0.28*
Listed	-0.634**	-0.623**	
	0.26	*0.26*	
Manufacturing	0.463***	0.451***	0.479***
	0.16	*0.16*	*0.16*
Construction	0.713**	0.633**	0.686**
	0.29	*0.29*	*0.29*
France	-0.359	-0.359	-0.413
	0.26	*0.26*	*0.26*
Germany	0.374*	0.339	0.377*
	0.22	*0.22*	*0.22*
Italy	0.560*	0.509	0.508
	0.33	*0.33*	*0.33*
Portugal	-0.819**	-0.861***	-0.875***
	0.32	*0.32*	*0.31*
Spain	-0.722***	-0.775***	-0.668***
	0.20	*0.19*	*0.20*
N	378	393	382
Log pseudolikelihood	-210.70	-217.99	-215.63
% correctly classified	70.37	70.23	70.68

Note: The underlying model is equation (1). The dependent variable is FinObst. Small firms employ 5-50 employees Young is a dummy variable which takes value 1 if the firm has less than 6 years. Listed firms are firms quoted on a stock exchange. Group indicates firms controlled by a company group. Standard errors (reported in italics) are robust and *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively. The percentage of correctly classified firms is the weighted average of the percentage of correct prediction (the cut off is 0.5) for each outcome, FinObst = 1 and FinObst = 0, with the weights being the fractions of zero and one outcomes, respectively. Source: WBES database and own calculations.

The third model specification is selected to work out the measure of financing obstacle, which is the model predicted probability of having financing obstacles [42]: first, I collect the

[42] Specification tests suggest to choose either specification (2) or (3). The latter one is then selected since it guarantees an higher percentage of correctly classified firms. However, the financial obstacle indices, computed in Amadeus for the three different specifications as the predicted probabilities of having financing obstacles, are highly correlated between each other: the correlations are above 95%.

coefficients of the variables in (3).[43] Second, for all the observations in AMADEUS I compute the linear prediction of the probit model. The predicted probability of having financing obstacles, which I call *FO*, is then the cumulative standard normal distribution evaluated at the linear prediction of the model. As Table 5.2 summarizes, Italian firms are those who have the highest estimated probability of facing financing obstacles. In addition, the minimum figure is 0.43, which is close to the average value in Germany.[44] FO, instead, is on average around 0.3 in France and Spain, and 0.2 in Portugal. In particular, for Portugal the WBES registered the lowest percentage of firms reporting financing obstacles and, in line with this, the lowest coefficient among the country dummies in the probit model.

Table 5.2 FO estimates. Summary statistics

	France	Germany	Italy	Portugal	Spain	Total
Mean	0.36	0.46	0.72	0.21	0.33	0.45
SD	0.14	0.13	0.11	0.10	0.13	0.22
Median	0.33	0.43	0.70	0.19	0.28	0.42
Min	0.12	0.24	0.43	0.05	0.24	0.05
Max	0.73	0.89	0.92	0.54	0.89	0.92

Note: FO is the predicted probability of having financing obstacles. The estimated probabilities of facing financing obstacles are calculated on the basis of the coefficients derived from a probit model estimated on the WBES database. Source: AMADEUS database and own calculations.

Table 5.3 investigates the growth rate of firms with high or low values of FO. The firm grouping is defined with respect to the percentile of FO in which firms fall: above the last decile (high), or below the first decile (low). In France, Germany, and Italy firms' growth rate is higher for enterprises with lower predicted probability of having financing obstacles. However, this is not the case in Spain. For Portugal, instead, the difference is not statistically different from zero.

Table 5.3 FO and firm growth

	France		Germany		Italy		Portugal		Spain	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
High FO	0.04	0.21	0.01	0.22	0.03	0.22	0.06	0.21	0.09	0.26
Low FO	0.05	0.18	0.05	0.15	0.06	0.19	0.05	0.19	0.07	0.20

Note: The table reports summary statistics for firm' growth rate belonging to the first (Low) or last decile (High) of FO. FO is the predicted probability of having financing obstacles. Source: AMADEUS database and own calculations.

[43] I also use the coefficients of the dummies for France and Italy since they are close to the significance threshold of 10%. The coefficient on group, instead, is set equal to zero.

[44] In the WBES, Germany recorded a percentage of companies reporting financing obstacles above that for Italy. The lower predicted probability of financing obstacles estimated here for the German firms in comparison to the Italian firms is linked to factors such as the higher percentage of large and listed companies, which, according to the results shown above, are negatively related to financial difficulties.

5.2 Step 3: the determinants of firm growth

Let now turn to the model for firms growth, which is estimated through a GMM- system.[45] Table 5.4 shows the mutual contemporaneous correlation coefficients among the regressors and the dependent variable.[46] Cash flow and growth of sales exhibit a positive correlation with firm growth above 20%. Consistently with previous analysis, indebtedness is weakly but positively related with firm growth, while debt burden coefficient is negative. Likewise, FO is negatively related to firm size, i.e. the natural logarithm of real total assets, firm growth and the availability of cash flow, while it is positively related with debt variables.

Table 5.4 Correlation matrix

Full sample	Growth of assets (it-1)	LnTotal Assets (it-1)	Young (it)	Growth of sales (it)	Cash flow (it-1)	Indebtedness (it-1)	Debt burden (it-1)
Growth of assets (it-1)	1						
LnTotalAssets (it-1)	0.0550*	1					
Young (it)	0.0752*	-0.0642*	1				
Growth of sales (it)	0.2199*	0.0009	0.1089*	1			
Cash flow (it-1)	0.2551*	-0.0894*	0.0211*	0.0161*	1		
Indebtedness (it-1)	0.0808*	-0.0393*	0.0983*	0.0443*	-0.3513*	1	
Debt burden (it-1)	-0.1121*	0.0391*	0.0254*	-0.0088*	-0.5132*	0.2693*	1
FO (it-1)	-0.0187*	-0.1365*	0.0825*	-0.0045*	-0.1011*	0.1703*	0.0345*

Note: The table reports the contemporaneous Pearson correlation coefficients among the variables of interest. Growth of assets is the difference between the natural logarithm of real total assets for two subsequent years. Young is a dummy variable which takes value 1 if the firm has less than 6 years. Growth of sales is the difference between the natural logarithm of real sales for two subsequent years. Cash flow is the sum of the per-period profit/losses and depreciation, scaled on the total assets at the beginning of the period. Indebtedness is the ratio between total debt and total assets. Debt burden is the ratio between interest paid and EBITDA. FO is the predicted probability of having financing obstacles. The * indicates that coefficients are significant at the 5% level. Source: AMADEUS Bureau van Djik Electronic Publishing and own calculations.

In Panel A of Table 5.5, I consider the classical LPE equation, equation (3). I always control for year and sectoral effects. The results clearly reject LPE in Germany and in Portugal, since current size affect firms growth. In France, Italy and Spain the validity of the instruments is not confirmed by the tests. However, the aim of the paper is to investigate the determinants of firms growth and to check whether the probability of facing financing obstacles negatively affects firms growth. Thus, I estimate three specifications of the augmented LPE model, equation (4). In particular, in Panel B I add to the standard LPE equation the dummy young and firms profitability, in Panel C I also consider indebtedness and FO, and in Panel D I include an additional measure of

[45] I use the program DPD98 for Gauss (Arellano and Bond, 1998).
[46] Summary statistics and correlation matrices at country level are reported in the Appendix.

financial pressure, interest payments on debt over results. All right-hand side variables are lagged one period to reduce possible endogeneity problems (except the growth rate of sales), and lagged values of the regressors are used as instruments.[47]

In the specifications B-D, the estimated coefficients of past firms' growth (the autoregressive parameter in equation (4)) are negative and significant, thus rejecting the LPE hypothesis of growth not depending on past performances. Hart (2000) argues that the relative importance of systematic and stochastic factors in the growth of companies may be indicated by the degree of serial correlation of growth. He suggests that systematic factors should produce persistent company growth and hence a high degree of serial correlation. The negative sign means that a period of above average growth tends to be followed by one of below average growth. Goddard, Wilson and Blandon (2002) argue that a negative autocorrelation coefficient might also support that annual growth rates are noisy.

A major implication of the LPE is that initial size also should not affect growth, something that does not seem supported in Panel C and D: in three out of the five analysed countries (France, Portugal and Spain) I find a negative and significant coefficient for the size measure, indicating that small firms grow faster, while for Germany the coefficient is positive when significant. In Italy, this variable is found to be significant only in Panel D.

Apart from Germany, the dummy young is always positive and significant. We could expect that older companies, with their larger accumulations of past output, to be further along the learning and experience curves ("learning by doing" argument), and hence to be able to grow more quickly as a result of these dynamic economies of scale. However, young firms usually are small firms and then they might growth faster, for instance to reach their Minimum Efficient Scale (MES). The present evidence of smaller and younger firms growing significantly faster in four out of five countries is consistent with Evans (1987a and 1987b) and Dunne, Roberts and Samuelson (1988 and 1989). The difference between growth for more and less mature firms seems specially marked in Italy, Portugal and Spain.

As expected, growth opportunities, proxied by growth of sales, have a positive and significant impact on firm growth for all the analysed countries.[48] This is particularly strong in Italy, where the coefficient ranges between 0.6-0.7. The availability of internal funds, proxied by cash flow, is particularly important for growth in France and Spain, where the coefficient is about 0.6, and in Italy (0.4). The cash flow variable remains significant also when the financing obstacles

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[47] These, reported in the Appendix, are not common across countries because of specification problems in some countries. Hence, the results are not strictly comparable across countries.

[48] The growth rate of sales is another common proxy for firm growth (see among the others Opler and Titman, 1994, Beck, Demirgüç-Kunt, and Maksimovic, 2005), thus, as a robustness check, I used it as dependent variable in the estimation of model (4). The results are very similar with respect to those obtained using the growth rate of assets.

indicator is included in the specification. Interestingly, when including FO, in three out of the five countries under analysis the magnitude of the cash flow variable decreases (even if not very drastically, see Table A.6 in the Appendix which adds the variable FO to the Panel B specification), while in Germany the coefficient becomes higher. This might be supporting the hypothesis that a positive and significant coefficient for cash flow indicates the existence of financing constraints. In fact, the link between cash flow and growth seems stronger in those countries for which the sample includes a higher percentage of smaller firms, which are those more affected by financial obstacles. Indeed, the marginal impact of cash flow on growth in France, Italy and Spain ranges between 0.4 and 0.6, while in Germany, where around 70% of the companies in the sample are large, this impact is much lower (around 0.2). The fact that this variable remains significant, when the financing obstacles indicator is included in the specification, might signal that the simple measure of financing obstacles used here could not fully capture financing constraints faced by firms. Alternatively, it could reflect the fact that cash flow is correlated with investment opportunities, which are linked to the growth of assets. When including both indebtedness and FO, the cash flow sensitivity rises to about 0.6 for Italy, while it declines for Portugal and it is fairly stable for the other countries (see Panel C).

As for indebtedness, the results are mixed. We might expect that higher leverage implies higher financial pressure, then difficult access to additional external funds and, as a result, a negative impact on firm growth. The results found in Germany and Portugal are in line with this hypothesis. However, in Italy and Spain, I find positive and significant coefficients, which are consistent with the results in section 3.2, and might be the outcome of companies with better growth opportunities being more successful in attracting external funds. In France, the coefficient on indebtedness has a much lower (positive) magnitude and it is significant only at 10% level.[49] In general, these results are in line with the previous evidence in literature, which is not conclusive regarding the impact of leverage on growth. In effect, mixed evidence on the relationship between leverage and growth is found by Opler and Titman (1994), who show that growth is lower for firms in the three highest deciles of leverage, but especially so within distressed industries. Also Lang, Ofek and Stulz (1996) find that the negative relationship between growth and leverage exists only for firms with low Tobin's Q, thus for firms with lower investment opportunities. When they split

[49] As stated above, a simple regression analysis seems to point in this direction. In addition, to further check for the role of growth opportunities, I added to the Panel C specification an interaction term between indebtedness and a dummy for low growth opportunities (i.e. firms in the first 5% of sales growth). I found for France, Germany and Spain a negative coefficient, while for Italy and Portugal this variable has the negative sign but it is not significant. Following Opler and Titman (1994) findings, I also tried to introduce an interaction term between indebtedness and small size, I obtained a negative sign in Italy, Portugal and Spain. In Germany, instead, it turned out that indebtedness has positive impact on growth for small firms. Finally, in France, this variable was not significantly different from zero.

their sample by size, they find that leverage has a positive effect on growth for large, highly levered firms that are not in distressed industries. Hesmati (2001) adopts various proxies for firm growth and finds that indebtedness negatively affects the growth rate of assets, positively affects the growth rate of sales, while it has no impact on employment.

In Panel C, the firm's predicted probability of having financing obstacles, FO, has the expected negative sign. Thus, although it is a function of a few qualitative determinants of financing obstacles, this measure seems to capture the negative impact of financing obstacles on firm growth. This is not the case in Germany, where the coefficient is positive but not significant. Spain is the country with higher growth sensitivity to FO, followed by Portugal, Italy and France.

In the last specification, Panel D, I add another measure of financial pressure to gain a better interpretation of the relationship between firms' financial position and growth. In line with the descriptive results in Figure 3.4, the coefficients of debt burden are negative. For Germany and Italy the coefficient is negative but not significant. In the latter country, however, the lower significance is linked to the fact that the standard error associated to the estimation of the coefficient is rather large. The magnitude of this coefficient is, in fact, very close to that obtained for France and Spain, where this variable is found to have a statistically (and negative) significant impact on growth. For Portugal the information required for calculating the debt burden ratio is not available in the AMADEUS database and hence this estimation could not be carried out.

The consistency of the results in Panels B-D is confirmed by the fact that second-order serial correlations test, i.e. M_2, is never rejected. Furthermore, the Sargan test of over-identifying restriction is, in most cases, above the standard 5% critical value, thus confirming the validity of the instruments matrix.[50]

Overall, past growth rates affect current growth in all the countries and LPE is rejected in Germany and Portugal. After controlling for growth opportunities as well as for financial factors, in Spain also small firms grow faster. In Italy and France results are less strong since sometimes the size measure is not significant. In general, smaller and younger firms grow faster. This evidence also suggests that firms' financial position matters in explaining firms' growth rates. However, while cash flow has always a positive impact on growth, results on leverage and debt burden are mixed. Finally, results indicate that the measure of financing obstacles derived from survey data appears to be relevant in explaining firms growth in four out of five countries.

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[50] The p-value associated to the Sargan test in Panel B for Spain is quite low, 2.2%, but the M_2 statistic indicate that the key condition for instruments validity holds. Blundell, Bond and Windmeijer (2000) document, through Monte-Carlo simulations, a tendency to over-rejection for this test.

Table 5.5 GMM-system results

Panel A										
	France		Germany		Italy		Portugal		Spain	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Const	0.008	0.048	-0.261***	0.097	0.008	0.015	0.340***	0.095	0.158***	0.017
Growth of assets $_{(it-1)}$	-0.074***	0.004	0.000	0.026	-0.079	0.110	0.021*	0.011	0.029	0.020
LnTotalAssets $_{(it-1)}$	-0.003	0.013	0.039***	0.014	0.019***	0.003	-0.059***	0.018	-0.031***	0.004
N	282,522		7,955		270,818		21,266		317,689	
M_1	0.00		0.00		0.00		0.00		0.00	
M_2	0.32		0.73		0.88		0.83		0.00	
Sargan	0.00		0.05		0.00		0.02		0.09	

Panel B										
	France		Germany		Italy		Portugal		Spain	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Const	-0.023	0.040	-0.115*	0.070	-0.007	0.015	0.100	0.073	0.061***	0.021
Growth of assets $_{(it-1)}$	-0.179***	0.011	-0.056*	0.031	-0.328***	0.108	-0.074***	0.022	-0.148***	0.034
LnTotalAssets $_{(it-1)}$	-0.013	0.010	0.015	0.010	-0.002	0.004	-0.023*	0.014	-0.025***	0.005
Young $_{(it)}$	0.016***	0.005	-0.004	0.015	0.032***	0.009	0.039***	0.013	0.035***	0.007
Growth of sales $_{(it)}$	0.237***	0.066	0.177**	0.073	0.696***	0.080	0.219***	0.068	0.213***	0.070
Cash flow $_{(it-1)}$	0.649***	0.060	0.204**	0.096	0.403***	0.104	0.343***	0.059	0.588***	0.041
N	282,522		7,955		270,818		21,266		317,689	
M_1	0		0.00		0		0		0	
M_2	0.97		0.63		0.44		0.20		0.43	
Sargan	0.05		0.21		0.06		0.18		0.02	

Note: The coefficients are the output of the one-step estimation of GMM system. Standard errors are robust. All the variables, apart from young and growth of sales are lagged for one period. The estimation period is 1996-2005 for France, and 1995-2005 for the remaining countries. Growth of assets is the difference between the natural logarithm of real total assets for two subsequent years. Cash flow is the sum of the per-period profit/losses and depreciation, scaled on the total assets at the beginning of the period. Indebtedness is the ratio between total debt and total assets. Debt burden is the ratio between interest paid and EBITDA. FO is the predicted probability of having financing obstacles. M_1 (M_2) is the p-value of the test for first (second) order serial correlations of the residuals; Sargan is the p-value of the test of over-identifying restrictions computed using the two-step residuals of the model, and *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table 5.5 (*continued*)

	Panel C									
	France		Germany		Italy		Portugal		Spain	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Const	0.034	0.05	-0.292	0.23	0.098	0.120	0.276***	0.07	0.075	0.08
Growth of assets (it-1)	-0.185***	0.01	-0.062**	0.03	-0.351***	0.096	-0.043**	0.02	-0.130***	0.02
LnTotalAssets (it-1)	-0.026***	0.01	0.033*	0.02	-0.016	0.010	-0.033***	0.01	-0.034***	0.01
Young (it)	0.035**	0.01	-0.074	0.05	0.067***	0.021	0.089***	0.02	0.098***	0.02
Growth of sales (it)	0.306***	0.05	0.184***	0.07	0.599***	0.067	0.129**	0.05	0.172***	0.05
Cash flow (it-1)	0.610***	0.06	0.208**	0.10	0.611***	0.126	0.285***	0.06	0.602***	0.04
Indebtedness (it-1)	0.034*	0.02	-0.181***	0.06	0.106***	0.030	-0.122***	0.04	0.130***	0.05
FO (it-1)	-0.125*	0.08	0.414	0.29	-0.216*	0.119	-0.265***	0.09	-0.337***	0.09
N	282,522		7,955		270,818		21,266		317,689	
M_1	0		0		0		0		0	
M_2	0.48		0.67		0.95		0.23		0.17	
Sargan	0.05		0.12		0.06		0.05		0.05	

	Panel D									
	France		Germany		Italy				Spain	
	Coeff	SE	Coeff	SE	Coeff	SE			Coeff	SE
Const	0.059	0.06	-0.262	0.22	0.146	0.122			0.124*	0.064
Growth of assets (it-1)	-0.174***	0.01	-0.064**	0.03	-0.345***	0.093			-0.124***	0.017
LnTotalAssets (it-1)	-0.025***	0.01	0.030*	0.02	-0.018*	0.010			-0.036***	0.007
Young (it)	0.038**	0.02	-0.068	0.05	0.070***	0.021			0.099***	0.017
Growth of sales (it)	0.288***	0.05	0.182***	0.06	0.571***	0.067			0.175***	0.046
Cash flow (it-1)	0.411***	0.10	0.172***	0.05	0.428**	0.192			0.492***	0.063
Indebtedness (it-1)	0.047**	0.02	-0.161***	0.05	0.110***	0.029			0.120***	0.037
Debt burden (it-1)	-0.030**	0.01	-0.008	0.01	-0.032	0.024			-0.031**	0.013
FO (it-1)	-0.133*	0.08	0.385	0.28	-0.228*	0.118			-0.341***	0.083
N	282,522		7,955		270,818				317,689	
M_1	0		0		0				0	
M_2	0.61		0.69		0.77				0.15	
Sargan	0.10		0.09		0.11				0.08	

6. Concluding remarks

This paper analyzed the impact of financing obstacles, as well as firm's characteristics and financial position, on firm growth for non-financial corporations in five euro area countries. The investigated determinants of firm growth were computed using both a firm-level survey and a large panel dataset. I developed a three step procedure. First, using survey data, I investigated the determinants of financing obstacles. I used as a proxy the perceived severity of collateral requirements as obstacles to firm growth and performance. I found that being young increases the probability of facing financing obstacles by 16%, and being small by about 13%. A 1% increase in firm performance in terms of sales, instead, reduces the probability of feeling constrained by nearly 4%. Then, combining different sources of information, I worked out a measure of the predicted probability of having (or feeling to have) financing obstacles and, as a final step, I directly evaluated its impact on firm growth using additional information derived from balance sheet data.

This procedure allowed to test the implications of both the stochastic and the deterministic approaches to firm growth. Differently from earlier literature, I estimated a dynamic model for firm growth through a GMM-system estimator. LPE is clearly rejected in Germany and Portugal. After controlling for growth opportunities, age and financial factors, I found that in Spain also small firms grow faster. The evidence for Italy and France is less clear-cut since sometimes the size measure is not significant. In general, consistently with previous findings, I had that smaller and younger firms grow faster. More importantly, I found that firm' financial position matters in explaining firms' growth rates. In particular, growth opportunities, measured by growth of sales, have a positive and significant impact on firm growth for all the analysed countries. This impact is particularly high in Italy, and lower in Germany and Spain. At the same time, the availability of internal funds, proxied by cash flow, is found to be important for growth in France and Spain, while a much lower coefficient is found in Germany. When I included a measure of leverage, namely debt to assets ratio, results were mixed. While in Germany and Portugal, leverage has a negative impact on growth, in the other countries the contrary holds. The descriptive analysis suggested that a different proxy for financial pressure, like debt burden, might provide more clear-cut evidence. I found that this variable, when significant, has a negative impact on growth. Finally, results indicated that the measure of financing obstacles derived from survey data appears to be relevant in explaining firms growth, though this measure is based on few variables that probably do not fully capture financial difficulties faced by firms. The negative effect of this latter variable is stronger for Spain, Portugal and Italy, and weaker in France. In Germany, where I also found a smaller impact of cash flow on firm growth, this variable is not significant.

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Appendix

Table A.1 Summary statistics

	N	Mean	SD	Median
General financing obstacle	472	0.43	0.49	0
Collateral requirements	453	0.37	0.48	0
High interest rates	458	0.49	0.50	0
Access to long-term loans	445	0.24	0.43	0
Bank paperwork/bureaucracy	463	0.44	0.50	0
Need special connection	453	0.28	0.45	0
Banks' lack of money to lend	444	0.18	0.38	0
Access to foreign banks	403	0.12	0.32	0
Access to non-bank equity	396	0.19	0.39	0
Access to export finance	353	0.17	0.37	0
Access to leasing finance	422	0.28	0.45	0
Inadequate credit/financial information	435	0.29	0.45	0
Corruption of bank officials	421	0.07	0.26	0

Note: The reported variables are computed as dummies taking value one if the financing obstacle is moderate-major and zero otherwise. Source: WBES and own calculations.

Table A.2 Correlation coefficients

	General financing obstacle	Collateral requirements	High interest rates	Access to long-term loans
Collateral requirements	0.4237*	1		
High interest rates	0.2464*	0.2492*	1	
Access to long-term loans	0.338*	0.3629*	0.2318*	1
Bank paperwork/bureaucracy	0.3532*	0.4255*	0.3064*	0.2658*

Note: The table reports the Pearson correlation coefficients among dummy variables taking value one if the financing obstacle is moderate-major and zero otherwise. The * indicates that coefficients are significant at the 5% level both to the standard and to the bootstrap significance tests. With respect to the standard significance test, let *r* be a calculated correlation coefficient and *n* the number of observations over which it is calculated, the unadjusted significance level is calculated as the reverse cumulative Student's t distribution with $n - 2$ degrees of freedom, evaluated at $\frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$. The bootstrap test is performed with 5,000 random resampling. Source: WBES and own calculations.

Table A.3 Summary statistics

France	Mean	SD	Median	Min	Max
Growth of assets	0.036	0.187	0.023	-0.621	0.748
TotalAssets	367.64	8,631.58	30.68	0.39	1,295,850.00
Young	0.068	0.252	0.000	0.000	1.000
Growth of sales	0.034	0.192	0.027	-0.961	1.139
Cash flow	0.089	0.098	0.078	-0.320	0.503
Indebtedness	0.703	0.231	0.716	0.063	1.776
Debt burden	0.452	0.996	0.113	-4.474	4.833
FO	0.359	0.136	0.332	0.120	0.735
Germany	Mean	SD	Median	Min	Max
Growth of assets	0.023	0.170	0.010	-0.673	0.870
TotalAssets	10,509.84	78,569.90	977.00	2.63	2,049,474.00
Young	0.098	0.297	0.000	0.000	1.000
Growth of sales	0.031	0.224	0.020	-1.383	1.388
Cash flow	0.081	0.082	0.072	-0.345	0.911
Indebtedness	0.676	0.193	0.696	0.082	1.397
Debt burden	0.387	0.831	0.156	-3.226	4.714
FO	0.464	0.130	0.426	0.241	0.895
Italy	Mean	SD	Median	Min	Max
Growth of assets	0.038	0.184	0.025	-0.623	0.699
TotalAssets	190.58	5,054.28	49.06	1.47	978,267.30
Young	0.034	0.182	0.000	0.000	1.000
Growth of sales	0.021	0.230	0.018	-1.468	1.164
Cash flow	0.064	0.069	0.049	-0.193	0.401
Indebtedness	0.772	0.174	0.812	0.182	1.141
Debt burden	0.501	0.831	0.248	-3.224	4.688
FO	0.719	0.113	0.700	0.430	0.922

Note: The figures are in million of euro. Source: AMADEUS Bureau van Djik Electronic Publishing and own calculations.

Table A.3 (*cont'd*)

Portugal	Mean	SD	Median	Min	Max
Growth of assets	0.045	0.183	0.025	-0.613	0.796
TotalAssets	544.72	4,755.82	64.38	2.29	205,723.00
Young	0.044	0.205	0.000	0.000	1.000
Growth of sales	0.027	0.237	0.020	-1.538	1.498
Cash flow	0.087	0.077	0.073	-0.143	0.427
Indebtedness	0.656	0.186	0.681	0.081	1.253
FO	0.208	0.102	0.186	0.048	0.540
Spain	Mean	SD	Median	Min	Max
Growth of assets	0.060	0.212	0.037	-0.630	0.819
TotalAssets	173.95	4,647.73	24.11	0.22	918,490.20
Young	0.083	0.275	0.000	0.000	1.000
Growth of sales	0.047	0.265	0.034	-1.352	1.708
Cash flow	0.093	0.086	0.078	-0.237	0.491
Indebtedness	0.662	0.218	0.690	0.076	1.482
Debt burden	0.369	0.628	0.196	-3.446	4.677
FO	0.325	0.132	0.282	0.097	0.715

Table A.4 Correlation coefficients

France	Growth of assets (it-1)	LnTotal Assets (it-1)	Young (it)	Growth of sales (it)	Cash flow (it-1)	Indebtedness (it-1)	Debt burden (it-1)
Growth of assets (it-1)	1						
LnTotalAssets (it-1)	0.0517*	1					
Young (it)	0.0476*	-0.0492*	1				
Growth of sales (it)	0.2137*	-0.0086*	0.0983*	1			
Cash flow (it-1)	0.2481*	-0.1105*	-0.0007	0.0262*	1		
Indebtedness (it-1)	0.0299*	-0.0759*	0.1112*	0.0340*	-0.2934*	1	
Debt burden (it-1)	-0.1338*	0.0502*	0.0360*	-0.0236*	-0.5431*	0.2821*	1
FO (it-1)	-0.001	-0.5399*	0.2405*	0.0380*	0.0457*	-0.0484*	-0.0291*
Germany							
Growth of assets (it-1)	1						
LnTotalAssets (it-1)	0.0786*	1					
Young (it)	0.0454*	-0.0442*	1				
Growth of sales (it)	0.1845*	0.0174	0.0894*	1			
Cash flow (it-1)	0.2404*	-0.0486*	0.0248*	0.0519*	1		
Indebtedness (it-1)	0.0328*	-0.0268*	-0.0305*	-0.0108	-0.1833*	1	
Debt burden (it-1)	-0.1041*	-0.0079	0.0139	-0.0337*	-0.4717*	0.1441*	1
FO (it-1)	-0.0335*	-0.6474*	0.3027*	0.0201	-0.006	0.0430*	0.0529*
Italy							
Growth of assets (it-1)	1						
LnTotalAssets (it-1)	0.1041*	1					
Young (it)	0.0612*	-0.0138*	1				
Growth of sales (it)	0.2392*	0.0198*	0.0693*	1			
Cash flow (it-1)	0.2408*	0.0136*	-0.0037	0.0270*	1		
Indebtedness (it-1)	0.0960*	-0.1000*	0.0789*	0.0432*	-0.4247*	1	
Debt burden (it-1)	-0.1158*	0.0146*	0.0137*	-0.0280*	-0.5135*	0.2409*	1
FO (it-1)	-0.0294*	-0.4908*	0.1445*	0.0171*	0.0021	-0.0152*	-0.0043*

Table A.4 (*cont'd*)

Portugal	Growth of assets (it-1)	LnTotal Assets (it-1)	Young (it)	Growth of sales (it)	Cash flow (it-1)	Indebtedness (it-1)	Debt burden (it-1)
Growth of assets (it-1)	1						
LnTotalAssets (it-1)	0.0382*	1					
Young (it)	0.0847*	0.0138*	1				
Growth of sales (it)	0.2386*	0.0288*	0.1308*	1			
Cash flow (it-1)	0.2547*	-0.0406*	0.0125	0.0470*	1		
Indebtedness (it-1)	0.1460*	-0.0367*	0.0875*	0.0518*	-0.3119*	1	
FO (it-1)	0.0217*	-0.4877*	0.1474*	0.0433*	0.0357*	-0.0241*	
Spain							
Growth of assets (it-1)	1						
LnTotalAssets (it-1)	0.0781*	1					
Young (it)	0.0982*	-0.0771*	1				
Growth of sales (it)	0.2105*	0.0184*	0.1308*	1			
Cash flow (it-1)	0.2712*	-0.0522*	0.0269*	-0.0124*	1		
Indebtedness (it-1)	0.1411*	-0.0960*	0.1429*	0.0754*	-0.3290*	1	
Debt burden (it-1)	-0.0836*	0.0095*	0.0371*	0.0311*	-0.4929*	0.2768*	1
FO (it-1)	0.0411*	-0.5148*	0.2812*	0.0582*	0.0211*	0.0881*	0.0125*

Note: The table reports the Pearson correlation coefficients. The * indicates that coefficients are significant at the 5% level. The significance level is computed as in table A.2. Source: AMADEUS Bureau van Djik Electronic Publishing and own calculations.

Table A.5 Instruments for GMM-system

	France		Germany		Italy	
	Level	Difference	Level	Difference	Level	Difference
Growth of assets	33	1	22	1	55	4
LnTotalAssets	55	X	33	2	XX	5
Young	34	X	23	X	22	X
Growth of sales	55	2	22	1	XX	5
Cash flow	33	X	22	1	XX	3
Indebtedness	45	4	33	1	XX	5
Debt burden	XX	5	24	2	XX	5
FO	XX	3	55	X	XX	4
	Portugal		Spain			
	Level	Difference	Level	Difference		
Growth of assets	33	1	55	2		
LnTotalAssets	33	X	22	X		
Young	25	X	33	X		
Growth of sales	44	3	66	3		
Cash flow	33	1	44	2		
Indebtedness	XX	1	33	X		
Debt burden			XX	2		
FO	35	1	XX	1		

Note: The table reports the instrument matrix for the GMM system estimation. Level indicates the lags used as instruments for the equation in differences, the digits are the minimum and maximum lags, respectively. Difference indicates the order of the differenced instruments for the equation in level.

Table A.6 Firm growth determinants

	France		Germany		Italy		Portugal		Spain	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Const	0.040	0.05	-0.399*	0.221	0.239**	0.119	0.105	0.075	0.255***	0.041
Growth of assets $_{(it-1)}$	-0.180***	0.01	-0.062**	0.030	-0.291***	0.099	-0.048**	0.019	-0.114***	0.03
LnTotalAssets $_{(it-1)}$	-0.020*	0.01	0.032*	0.017	-0.020*	0.011	-0.018	0.013	-0.050***	0.01
Young $_{(it)}$	0.040***	0.02	-0.072	0.051	0.073***	0.022	0.075***	0.017	0.126***	0.02
Growth of sales $_{(it)}$	0.258***	0.06	0.177*	0.071	0.653***	0.074	0.136**	0.054	0.154***	0.057
Cash flow $_{(it-1)}$	0.643***	0.06	0.213*	0.096	0.399***	0.101	0.302***	0.059	0.568***	0.041
FO $_{(it-1)}$	-0.132*	0.08	0.414	0.291	-0.276**	0.124	-0.192*	0.096	-0.473***	0.087
N	282,522		7,955		270,818		21,266		317,689	
M_1	0		0		0		0		0	
M_2	0.90		0.65		0.42		0.24		0.27	
Sargan	0.06		0.27		0.01		0.10		0.01	

Note: The table reports results for the estimation of the model in equation (4). The coefficients are the output of the one-step estimation of GMM system. Standard errors are robust. All the variables, apart form young and growth of sales are lagged for one period. The estimation period is 1996-2005 for France, and 1995-2005 for the remaining countries. Growth of assets is the difference between the natural logarithm of real total assets for two subsequent years. Cash flow is the sum of the per-period profit/losses and depreciation, scaled on the total assets at the beginning of the period. Indebtedness is the ratio between total debt and total assets. Debt burden is the ratio between interest paid and EBITDA. FO is the predicted probability of having financing obstacles. M_1 (M_2) is the p-value of the test for first (second) order serial correlations of the residuals; Sargan is the p-value of the test of over-identifying restrictions computed using the two-step residuals of the model, and *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

CHAPTER 2

THE PRICING OF THE OPTION IMPLICITLY GRANTED BY THE ITALIAN TREASURY TO THE SPECIALISTS IN THE RESERVED AUCTION REOPENING*

Abstract

The Italian Government Security primary market relies on a *primary dealer system*, i.e. the Treasury selects a group of intermediaries called *Specialists*, who benefit from a set of obligations and privileges attached to their status. Academic literature paid scant attention to one of the main privileges, namely the right to participate in reserved auction reopenings. This consists in the right to buy predetermined additional quantities of Government securities at the price settled at the auction. This paper attempts to price this privilege as a call option written on the auctioned bonds in the framework of the Cox – Ingersoll – Ross model. No matter the one-day life, the option has a value significantly different from zero. Moreover, the option value helps explaining part of the mispricing occurring on auction days between the primary and secondary market.

Keywords: Term structure of interest rates, option pricing, Treasury auctions, mispricing.

JEL Classification: D49, E43, G13, H63.

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1 Introduction

One of the most important functions of the Italian Treasury is to finance the public debt at the lowest possible cost for a given level of risk. This makes a correct pricing of Government Securities (GS) extremely important. To this aim, the revenue-raising abilities of the issuance mechanism of GS is crucial, giving great prominence to the study of market conditions, security design and placement techniques. One of the most important elements of the latter is the adoption, as in many other countries (Arnone and Iden, 2003; Bagella et al., 2007), of a *primary dealer system* to ensure the full placement of GS (Sareen, 2006).

More specifically, the Treasury selects a group of intermediaries among the Primary Dealers of the official electronic wholesale secondary market for the Italian GS, *Mercato Telematico dei titoli di Stato* (MTS).[1] These are called *Specialists in GS*[2]; the status of Specialist implies several obligations and privileges. Among the former, the most important is that Specialists should buy at least 3% of the auctioned securities throughout the year. Other obligations include liquidity provision on both the spot and the repo markets. On the other hand, only Specialists are rewarded by the Treasury with highly remunerative debt management operations.[3]

The present research aims to provide a method to quantify the value of an important privilege accorded to Specialists, namely their exclusive access to reserved auction reopenings (also known as non-competitive bids) following the auctions of medium-long-term bonds.[4] The reserved reopening gives to the Specialists the right to buy predetermined additional quantities of GS at the price settled at the auction. The application deadline is fixed at 3.30 p.m. of the business day following the auction.

As pointed out by Mohanty (2002), the issue of whether and to what extent non-competitive bids should be allowed depends on specific objectives. Some countries' objective is to encourage retail participation and protect them from the winner's curse. Other countries,

[1] MTS is the leading market in Europe for the trading of fixed income securities, with average transaction volumes above 75 billion euros a day in 2006. In this study I refer to MTS Italy – Cash. This is a regulated market pursuant to Section 66 of the Legislative Decree N.58, 24/2/1998, and operated by MTS S.p.A. under the supervision of the Bank of Italy and CONSOB. The Ministry of Economy monitors the operations of the government bond market by verifying and authorising amendments to the MTS rules.
[2] See the Republic President Decree (D.P.R.) N.398, 30/12/2003.
[3] The Annex to the Public Director Decree N.140483, 29/12/2005, explains in detail the set of obligations and privileges for the Specialists.
[4] Six-month zero coupon bonds (BOTs, Buoni Ordinari del Tesoro) are also offered in reserved reopenings. They are excluded from the analysis. Also 15-year and 30-year fixed coupon bonds are excluded from the analysis since they are mainly placed through syndicated placements.

like Italy, allow primary dealers to participate in non-competitive bids as a special privilege for their market-making role. From the issuer's point of view, the reserved reopening mechanism could increase the investor base by attracting those investors who would otherwise stay away from the auction, fearing that the price would be too high; it also increases the certainty about full subscription of the issue.

Following the intuition by Black and Scholes (1973) and Merton (1973) that many claims can be thought of as contingent claims, the reopening mechanism can be modelled as a *call* option written by the Treasury with a strike price equal to the *marginal* price[5] of the auction. Since bond options are sensitive to movements in the underlying interest rate, the option pricing requires the selection of a model for the term structure of interest rates. As reviewed either in academic literature (Sundaresan, 2000; and Rebonato, 2003) and in publications for the financial industry (for instance, Brigo and Mercurio, 2007), there exists a vast literature about term structure models. After a brief comparison between the exploitable arbitrage conditions, the Cox, Ingersoll and Ross (1985) framework (CIR) is chosen. This model guarantees positive interest rates and closed form solutions for both the price of bonds and of bond options. In addition, as this model was applied to Italian data in different points of time, the present work could be directly comparable to several studies. In particular, I consider as benchmark studies Barone, Cuoco and Zautzik (1991), and Bernaschi, Torosantucci and Uboldi (2007). This model choice is also motivated by data availability. Indeed, as data on derivatives written on Italian bonds are not available, I chose a model whose parameters can be estimated using the available bond prices. More specifically, I estimate the one-factor time-homogeneous version of the CIR model through the non-linear least squares method by cross-section on daily closing bond prices, as quoted on the MTS.

Even if, for the sake of option pricing, it is needed to calibrate the model just in correspondence of the auction days, I do it for all the trading days in the period 2004-2005. The goal is to assess the performance of the chosen model for the term structure of interest rates and to contrast it with the two benchmark studies.

I find that on some days the CIR model fits worse the data with respect to other days in the sample. I put forward, as possible explanations, either an intrinsic lack of the model, or, when these days correspond to auction dates, price manipulation by strategic market makers as in Drudi and Massa (2005). The analysis of the model residuals does not accept the hypothesis of a severe lack of the model in fitting the data, and only partially explains the

[5] BTPs are auctioned through marginal (or uniform price) auction system, see below for further details.

poorer performance in terms of insufficient liquidity of some assets. Since only aggregated data are available, the hypothesis of price manipulation is tested indirectly focusing on auctioned GS. Evidence suggests that auctioned GS do not significantly affect the goodness of fit of the model.

Once ruled out the possibility of obtaining misleading parameters from the model, the CIR pricing formula along with the Jamshidian (1989) result are exploited to compute the price of the call option written on the auctioned bonds. In particular, these are medium and long term fixed coupon bonds, BTPs (Buoni Poliennali del Tesoro), and 2-year zero coupon bonds, CTZs (Certificati del Tesoro Zero Coupon). The option value turns out to be significantly different from zero and higher for coupon bonds with respect to zero coupon bonds.

In addition, the pricing of this privilege is useful to evaluate the complex interplay between the issuer and the Primary Dealers. A visible effect is the *mispricing* detected when the prices at which Treasury bonds are sold in auction are higher (*overpricing*, see Pacini, 2007) or lower (*underpricing*, see Drudi and Massa, 1995; Scalia, 1998; and Pacini, 2006) than the when-issued[6] or secondary market prices. Since Specialists get almost the entire auction, the sign of mispricing presumably depends on the above-mentioned obligations and privileges. For instance, overpricing may be partially explained by Specialists aggressive behaviour during the auction to obtain the right to participate to other special issues.[7] The quantitative measurement of such obligations and privileges, in terms of cost and profits, is then necessary to make a complete assessment of the whole placement mechanism. The pricing of the option implicit in the reserved auction reopening is part of this assessment. It turns out that the benefits from the option balance, at least partially, the costs from overpricing.

The rest of the paper is organized as follows: section 2 investigates the characteristics of the reopening mechanism, surveys the most popular approaches to model the term structure of interest rates, and presents the pricing model; section 3 describes the dataset and discusses the performance of the chosen model; section 4 works out the value of the reserved reopening; section 5 relates the results to the mispricing phenomenon; section 6 concludes.

[6] These prices relate to new lines of GS that will be issued in the following days but that are already traded on the so called when-issued or gray market. The purpose is to enhance the price formation on the primary market.
[7] Among the various criteria, the Treasury ranks Specialists according to the quantity they are awarded in the auctions. The higher ranked gain the privilege to participate in other particular and highly remunerative operations on the primary market such as syndicated issuances, buybacks, operations in derivatives and in foreign currency.

2 Reserved Auction Reopening and Pricing Model

In this section I analyse the reserved reopening mechanism and I make some assumptions in order to quantify its value. Moreover, after a brief review of the literature about the term structure models of interest rates, I present selected model.

2.1 The reserved reopening mechanism

In 1994 the reserved reopening (henceforth RR) was introduced as a privilege for the Specialists participating in the ordinary auction. Since then, the time available to exercise the RR right has been getting longer. For instance, after June 27th 2000 the deadline for bidding at the ordinary auction, and then the RR right's starting time, was anticipated from 1.00 p.m. to 11 a.m.. Moreover, after January 15th 2005, the submission deadline for the RR changed from 12.00 a.m. to 3.30 p.m..

Table 2.1 Reserved auction reopenings

Bond type	N	Exercise rate (%)	Exercise rate Total (%)	Exercise rate Partial (%)	Supply (mln)	Demand (mln)
10-year BTP	20	45.00	88.89	11.11	7,475	2,650
5-year BTP	18	50.00	88.89	11.11	5,875	2,825
3-year BTP	21	42.86	88.89	11.11	8,575	2,941
CTZ 24m	21	38.10	62.50	37.50	6,900	1,134
TOT	80	43.75	82.86	17.14	28,825	9,550

Note: Elaboration on auction results available on the Italian Treasury website for the period 2004-2005.

Table 2.1 summarizes the analysed RRs and their exercise rate for the GS in the years 2004 and 2005. *Total* indicates that Specialists bought the total amount offered in the RR. Overall, the participation in RRs is around 44% and it is higher for coupon bonds with respect to zero coupon bonds. When Specialists submit bids for the RR, it is usually for the whole available quantity. Indeed, partial exercise ranges from about 10% for BTPs to about 38% for CTZs.[8] The last two columns of the table report the total quantity offered in RRs and the quantity allotted to Specialists. Only around one third of the offered quantity is effectively allotted. There are a few reasons why the privilege is not exercised or only partially exercised. For instance, Specialists are evaluated according to the quantity they buy in the ordinary auction, therefore they have an incentive to bid aggressively even if they have not a final investor who is buying the issued bonds. This generates inventory costs. Since the quantity

[8] If we split the sample in sub-periods 2004 and 2005, the total exercise rate is around 39% and 49%, respectively. Moreover, the partial exercise rate falls from about 21% in 2004 to about 15% in 2005.

bought in RR does not enter in such evaluation, the RR privilege is exercised when either the inventory costs are low or the Specialist can profit from it.

The participation in the RR is a right to buy, and it is not mandatory. Therefore, following the intuition by Black and Scholes (1973) and Merton (1973) that many claims can be thought of as contingent claims, the RR privilege can be considered as plain vanilla *call* option written by the Italian Treasury. In order to value it, we need to figure out the option type, the strike price, the expiration date, and the quantity of the underlying asset. The RR gives to Specialists the right to buy a predetermined quantity of the auctioned bond at the price settled at the auction. Hence, the option strike price should equal the marginal price.[9] However, the marginal price includes a placement fee that the Treasury pays to the Bank of Italy. This fee is due as reimbursement to the Specialists; in fact, they cannot apply subscription fees to their final clients.[10] Therefore, the strike price of the option is the difference between the marginal price and this fee.

Table 2.2 Reserved reopening timeline

Auction day		
11.00 a.m.	-	deadline for bids submission in the ordinary auction
	-	the RR privilege comes to life
Auction day +1		
3.30 p.m.	-	deadline for participation in the RR
Auction day +2		
	-	settlement day for both the first auction and the RR placements

Note: The table reports the timeline of the option expressed in business days. Until January 15th 2005 the deadline for the participation in the RR was 12.00 a.m..

Table 2.2 reports the timeline of the RR mechanism. The option can be exercised from 11.00 a.m. of the auction day to 3.30 p.m. of the following business day, hence it lasts about one day.[11] In principle, each Specialist is able to exercise the option at any time. For instance, as soon as the underlying asset price on the secondary market exceeds the strike price, he just has to short sell the underlying and place a bid for the RR. Thus, we might decide to model

[9] BTPs are auctioned through a marginal auction system. The marginal auction settles that all the requests are auctioned at the same price, the marginal price. Every dealer can submit a maximum of 3 bids. The marginal price is determined by satisfying bids starting from the highest price until the total amount of bids accepted equals the amount offered. The price of the last successful bid is the marginal price.

[10] The fee is equal to twenty basis points for the 3-year BTPs and CTZs, thirty for the 5-year BTPs and forty for the remaining securities.

[11] Since in the pricing formula the option's time to expiration is measured in days, the change in the time for the participation in the RR on January 15th 2005 is not considered.

the option as an American call. However, given its short life it is convenient to model it as a European one.[12] The settlement day is the same both for the ordinary auction and for the supplementary placement according to the calendar set at the beginning of the year.

The RRs are set up for a maximum amount equal to 25% of the amount offered in the first *tranche* of every new line of GS and to 10% for the following placements.[13] Each Specialist is entitled to a minimum share of the total amount issued. This fraction equals the sum of the quantities awarded in the last three auctions for the same security, excluding the RRs, divided by the quantity allotted to all the Specialists in the same auctions. Only those Specialists who took part in the ordinary auction are allowed to participate in the RRs. Bids are satisfied by first assigning to each Specialist the lesser between the amount requested and the amount rightfully due to him. Should one or more Specialists present bids inferior to those rightfully due, or not present any bid at all, the difference is allocated to dealers who presented bids greater than those rightfully due.[14]

In what follows it will be assumed that:

1. The option is evaluated on the day of the ordinary auction at 11.00 a.m.;
2. The option is evaluated from the Specialists' viewpoint;
3. The option is written on a bond whose face value is 100.

Assumption 2 implies that GS that tend to be mispriced by pricing models because they are illiquid should not be excluded from the sample. In effect, a financial institution also buys and sells illiquid bonds, and the term structure estimation should also consider this kind of securities.

2.2 Review of literature

As reviewed by Sundaresan (2000), in certain core areas in finance, such as derivatives valuation and term structure theory, continuous-time methods have proved to be "the most attractive way to conduct research and gain economic intuition". In this framework, the seminal contributions on option pricing by Black and Scholes (1973) and Merton (1973) set the beginning of a large literature in this area of research. These scholars, by forming a portfolio of the underlying stock coupled with borrowing, and continuously rebalancing the

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[12] In addition, the underlying securities make no payments during the life of the option, hence early exercise is never optimal and European and American calls have the same value (Merton, 1973).

[13] Country experience suggests that a limit of 20% is generally preferred for RRs to ensure that competition would not be reduced. Some countries also prefer to place a limit on the quantum of non-competitive bids by any individual bidder (Mohanty, 2002).

[14] Ex art. 12 of the Issuance Decree. See, for instance, http://www.dt.tesoro.it/ENGLISH-VE/Public-Deb/Italian-Go/Medium-Lon/index.htm.

portfolio, show that the payoffs of a call option can be replicated. Until Cox and Ross (1976a, 1976b) introduced the idea of risk-neutral valuation, the use of replicating portfolios was the basis for valuing options. Only a few years later Harrison and Kreps (1979) developed a theoretical framework for risk-neutral pricing, and clarified its connection to no-arbitrage in models with continuous trading.[15]

Until now only Brandolini (2004) attempted to work out the value of the RR as a call option, and she assumed the framework of Black and Scholes (1973). Although for some classes of derivatives B&S's assumption of constant risk free rate can be maintained, for instance for options on shares, in general this assumption may not be correct. In particular, when dealing with interest rate derivatives, movements in interest rate are at the basis of the existence of such instruments. Indeed, bond options are sensitive to movements in the underlying interest rate, r_t. Assuming a constant interest rate would mean that the bond price is completely predictable and, as a consequence, its volatility should equal zero. If this is the case there would be no bond options.[16] This paper departs from the B&S environment and makes use of an alternative pricing model. In particular, we need a model for the term structure of interest rates.

The selection of a proper model involves a number of considerations. With respect to the arbitrage condition, there are two approaches that can be followed, the *classical* and the HJM (Heat, Jarrow and Morton, 1992) ones. In the classical approach, a risk-adjusted model for spot rate under the risk neutral martingale measure is worked out from the price of arbitrage-free bonds. This approach requires the estimation of the drift and the volatilities of the spot rate dynamics, dr_t. Moreover, the spot rate is assumed to be Markovian, and consequently dr_t depends only on r_t. The fundamental theorem of asset pricing places no restrictions on what the drift should be since the spot rate is not the price of an asset. The advantage of this method is that one is able to price interest sensitive instruments without considering the markets for these securities; therefore it could be helpful in determining the price of the implicit option that, by definition, is not traded. Furthermore, it takes the advantage of the liquidity of the Italian secondary GS market. However, the traditional approach has several disadvantages. For instance, the drift of the instantaneous spot rate under

[15] In their paper, they show that the absence of arbitrage implies the existence of a risk-neutral probability measure. This technique is now extensively used for pricing options.
[16] Longstaff (1993) documents the different properties of option prices computed in the Cox, Ingersoll and Ross (1985) term structure framework with those implied by the Black-Scholes model.

the risk-neutral martingale measure is not directly observable, thus it is almost impossible to verify the consistency of the assumed dynamics with time series data.

The HJM, on the other hand, exploits the arbitrage relation between forward rates and bond prices to impose restrictions on the dynamics of instantaneous forward rates directly. By doing this, it eliminates the need to model the expected rate of change of r_t, but volatilities remain to be estimated. The HJM approach has been later applied to discrete-tenor forward rates in a series of studies that started with the seminal paper by Brace, Gatarek and Musiela (1997). Models based on assumptions regarding the evolution of discrete-tenor forward rates are known as BGM models, market models or LIBOR market models. The modern approach has several advantages over the classical approach. For instance, the consistency of the assumed dynamics for forward rates with time series data can be easily verified because the volatilities of forward rates are the same under the martingale measure and under the true (historical) probability measure. Moreover, an exact fit of the initial term structure is obtained by construction, since the initial forward curve is exogenous to the model. One disadvantage of the modern pricing approach is that arbitrary specifications of the forward rate volatilities will in general lead to non-Markovian dynamics, thus requiring the simulation of a large number of state variables. Among the others Sundaresan (2000), Rebonato (2003), and Brigo and Mercurio (2007) provide a review and analysis of these issues.

2.3 The CIR model

Within the classical framework, the chosen model is the one-factor time-homogeneous CIR.[17] The general equilibrium model, developed by Cox, Ingersoll and Ross (1985), led to the introduction of a square root term in the diffusion coefficient of the instantaneous short-rate dynamics proposed by Vasicek in 1977. The resulting model has been a benchmark for many years, as it remains useful because of its analytical tractability and the fact that, contrary to Vasicek (1977), the spot rate is always positive. Moreover, it provides closed form solutions for both the price of bonds and of bond options. In addition, several previous studies apply this model to Italian data, hence the present work could be directly comparable to them. In particular, I consider as benchmark studies Barone, Cuoco and Zautzik (1991), henceforth BCZ, and Bernaschi, Torosantucci and Uboldi (2007).

[17] The one-factor version of the CIR model assumes that: i) the instantaneous interest rate follows a square root process; ii) the local expectations hypothesis holds, i.e. the expected instantaneous return on bonds of any maturity is equal to the interest rate plus a risk premium; iii) the perfect market assumptions apply.

This model choice is also motivated by data availability. Although GS secondary market prices at various frequencies are available from different data vendors[18], and daily data can be found for free on the internet[19], derivatives written on the Italian GS are mainly traded over the counter, thus data are not easily available. This limited the selection to a model whose parameters can be estimated using only bond prices.[20]

Under the CIR model the instantaneous interest rate, r_t, follows the square root process described by the following stochastic differential equation:

$$dr_t = \kappa(\theta - r_t)dt + \sigma\sqrt{r_t}\,dw_t \tag{1}$$

where κ is the speed of adjustment of the interest rate towards its long-run average θ, $\sigma\sqrt{r_t}$ is the volatility of changes in the instantaneous interest rate, and dw_t is a standardized Wiener process. Moreover, if $0 < \kappa < 1$, the process is mean-reverting, i.e. the interest rate converges to its long-run value θ. The CIR model possesses an *affine term structure*[21], that is the price of a pure discount bond with residual maturity $\tau = T\text{-}t$ can be written as:

$$P(r,t,T) = F(t,T)e^{-G(t,T)r} \tag{2}$$

where

$$F(t,T) = \left[\frac{\phi_1 e^{\phi_2 \tau}}{\phi_2\left(e^{\phi_1 \tau} - 1\right) + \phi_1}\right]^{\phi_3} \tag{3}$$

and

[18] For instance data for bonds and notes traded on the MTS platform are provided by Bloomberg LP, Interactive Data Comstock, E-class/Class Editori, Ecowin, Fininfo, FTID, Il Sole 24 Ore, Infotec, Kestrel Inc., Moneyline Telerate, Reuters, Russell Mellon, SIA Cedborsa, Telekurs Financial, Thomson Financial, Traderforce, Valuelink Information.

[19] Daily data are available at http://www.mtsdata.com/content/data/public/mts/bulletin/. The time horizon is limited to one year.

[20] The CIR parameters could be also estimated from interest rates or swap rates. However, given that the object of analysis are options on Italian GS, the most natural choice to use the prices of the underlying bonds.

[21] See, for instance, Dai and Singleton (2000).

$$G(t,T)=\frac{e^{\phi_1\tau}-1}{\phi_2\left(e^{\phi_1\tau}-1\right)+\phi_1} \tag{4}$$

This means that the price of a pure discount bond with residual maturity τ is a function of the state variable, r, and of the three parameters, ϕ_1, ϕ_2 and ϕ_3, where:

$$\phi_1=\sqrt{(\kappa+\lambda)^2+2\sigma^2} \tag{5}$$

$$\phi_2=\frac{\kappa+\lambda+\phi_1}{2} \tag{6}$$

$$\phi_3=\frac{2\kappa\theta}{\sigma^2} \tag{7}$$

and $-\lambda$ is the market price of risk. Given *P(r,t,T)* the whole term structure of interest rates, *R(r,t,T)*, can be worked out using the well known relationship:

$$R(r,t,T)=\frac{-\ln[P(r,t,T)]}{T-t} \tag{8}$$

In particular, this implies that the instantaneous and the long-term rates are respectively:

$$R_0=\lim_{T\to t}R(r,t,T)=r \tag{9}$$

$$R_\infty=\lim_{T\to\infty}R(r,t,T)=(\phi_1-\phi_2)\phi_3 \tag{10}$$

and

$$\sigma=\sqrt{2\left(\phi_1\phi_2-\phi_2^2\right)} \tag{11}$$

The CIR parameters have been estimated with different methods. For estimations using non-linear regression techniques, see Brown and Dybvig (1986), Brown and Schaefer (1994) and, on Italian data, BCZ (1989, 1991) and Bernaschi, Torosantucci and Uboldi (2007). This method provides a time-series estimates of the unknown parameters, and it does not allow for a constant relation among the variables over the total observation period, because it is not possible to consider the temporal information contained in bond prices. Both de Munnik and Schotman (1994) and Zeytun and Gupta (2007) contrast the cross-sectional and the time series estimation of both the CIR and Vasicek models.[22] An alternative approach, based on the generalized method of moments (GMM), has been used by Longstaff (1989), Logstaff and Schwartz (1992), and Gibbons and Ramaswamy (1993). This approach implies placing some restrictions on the moments of bond yields. However, the procedure has some difficulties in valuing long-term coupon bonds. On Italian data, Gentile and Renò (2005) adopt the efficiency method of moments developed by Gallant and Tauchen (1996). A maximum likelihood approach, to estimate a multifactor version of the CIR model, has been proposed by Chen and Scott (1993) and Pearson and Sun (1994). The maximum likelihood method combines time series information and cross-sectional information, but its implementation is rather complex. Lamoureux and Witte (2002), instead, use advances in Bayesian estimation methods to exploit both time-series and cross-sectional restrictions of the CIR model. Finally, Ananthanarayanan and Schwartz (1980) develop a two-stage method.[23]

I adopt the one-stage approach developed by Brown and Dybvig (1986). This assumes that if we consider a coupon bond that entitles the holder to a vector of remaining payments, *cf*, to be received in a vector of dates, *d*, the value of such bond at time *t* is equal to:

$$V^*(t, cf, d) = \sum_{d_i > t} cf_i P(r, t, d_i) \tag{12}$$

Consistently, a zero coupon bond can be represented as a bond with a single payment at its maturity date. To estimate the parameters of the model, it is assumed that the bond market price V at time t deviate by the model price V^* by an error term, ε_t:

$$V(t, cf, d) = V^*(t, cf, d) + \varepsilon_t \tag{13}$$

While Brown and Dybvig assume that the error term is zero-mean and independent and identically distributed as a Normal, I follow BCZ (1989, 1991) and assume that pricing errors are increasing in the bond's duration. This is equivalent to assume that a pricing error is smaller the closer is the bond maturity date. Therefore, in order to make the error term

[22] Zeytun and Gupta (2007), for instance, suggest that if data are not smooth and well-behaved, time dependent models would be better in explaining the features of the term structure.
[23] Among the others, Overbeck and Ryden (1997) compare the asymptotic properties of various estimators.

homoskedastic, both sides of the previous equation should be divided by the square root of the product between the modified duration and the *cum-coupon* price of the bond. The resulting model is of the kind:

$$Y = XP(\tau, \beta) + u \tag{14}$$

where X is the cash flows' matrix, P the vector of prices, β the vector of the parameters, and u the error term. Since quoted prices are clean prices, i.e. they do not incorporate the coupon that has been maturing from the last payment date, this must be taken into account when estimating the CIR parameters.[24]

2.4 Option price

Given the calibrated parameters it is possible to price the option. Let $c(r,t,T,s,K)$ be the price of a call option with strike price K and maturity T, written on a pure discount bond with maturity s ($s > T > t$). As in Cox, Ingersoll and Ross (1985) the price of this option is:

$$c(r,t,T,s,K) = P(r,t,s)\chi^2(d_1, df_1, nc_1) - KP(r,t,T)\chi^2(d_2, df_2, nc_2) \tag{15}$$

where $\chi^2(d, df, nc)$ is the non-central chi-square distribution function valued at point d, with df degree of freedom and non-centrality parameter nc. These parameters are specified by Cox, Ingersoll and Ross (1985) as[25]:

$$d_1 = 2r^*[\varphi + \psi + G(T,s)] \tag{16}$$

$$d_2 = 2r^*(\varphi + \psi) \tag{17}$$

$$df_1 = df_2 = 2\phi_3 \tag{18}$$

$$nc_1 = \frac{2\varphi^2 r e^{\phi_1(T-t)}}{\varphi + \psi + G(T,s)} \tag{19}$$

$$nc_2 = \frac{2\varphi^2 r e^{\phi_1(T-t)}}{\varphi + \psi} \tag{20}$$

[24] Dirty prices, or cum-coupon prices, are computed as the sum of the accrued interest and the quoted (clean) prices.

[25] Jamshidian (1992) provides an alternative formulation.

$$\varphi = \frac{2\phi_1}{\sigma^2 \left[e^{\phi_1 (T-t)} - 1 \right]} \tag{21}$$

$$\psi = \frac{2\phi_2}{\sigma^2} \tag{22}$$

$$r^* = \frac{\ln\left[\frac{F(T,s)}{K} \right]}{G(T,s)} \tag{23}$$

where r^* is the critical interest rate below which the option will be exercised, and it is obtained solving $K = P(r^*, T, s)$. The option formulation tells us that the replicating strategy is simply to buy $\chi^2(d_1, df_1, nc_1)$ pure discounts bonds with maturity s and sell $K\chi^2(d_2, df_2, nc_2)$ pure discount bonds with maturity T.

Since the options to be considered here are written on coupon bonds, we have to take it into account. In particular, it can be proved that in one-factor models the option written on a coupon bond is equivalent to a portfolio of options on pure discount bonds (Jamshidian, 1989)[26]:

$$c(r,t,T,s,cf,K) = \sum_{j=q}^{m} cf_j c(r,t,T,s_j,K_j,0) \tag{24}$$

where cf_j is the bond's payment at time s_j $(T < s_q \leq s_j \leq s_m)$, r^* is the solution of $K = \sum_{j=q}^{m} cf_j P(r^*, T, s_j)$ and K_j the solution of $K_j = P(r^*, T, s_j)$.

Hence, given the formula for the price of a call option on pure discount bonds, we obtain:

$$c(r,t,T,s,cf,K) = \sum_{j=q}^{m} cf_j \left[P(r,t,s_j) \chi^2(d_{1,j}, df_{1,j}, nc_{1,j}) \right] - KP(r,t,T)\chi^2(d_2, df_2, nc_2) \tag{25}$$

[26] Longstaff (1993) obtains the same formula through a different approach.

3 Data and Calibration Results

Since the model parameters are estimated cross-sectionally on a daily basis, we should focus on auction days only. However, the model is calibrated over all the days in the sample. The goal is to assess its performance against previous studies on Italian data. In this section I present the data, and then I discuss the calibration results.

3.1 Data

The analysis is carried out for years 2004 and 2005. Both primary and secondary market prices are needed to price the RR privilege. With respect to the former, the auction results are provided online without restrictions by the Treasury. Results include information on the issued bond characteristics, the amount offered, bid and allotted, the settlement date, the settlement price, the gross yield and the coupon accrued days. Moreover, the results report the amount offered, bid and allotted in the RR. My sample includes 80 ordinary auctions on 3-5-10-year BTPs and 2-year CTZs.[27] These GS represent about 64% of the outstanding bonds in the period under analysis.

With respect to the secondary market, the model is calibrated on Italian GS traded on MTS during the same period. I end up with a total of 514 trading days.[28] These data come from *MTS Time Series* database. *MTS Time Series* package contains both high frequency tick data and daily data. In particular, I use daily quote information taken at 5.00 p.m.[29] Central European Time (CET) and an identifying cross-sectional file providing bonds description. This data source is probably the most informative since it refers to the market where Specialists are selected and have to fulfil their obligations.

Index linked bonds are excluded from the sample. For each trading day the dataset includes the closing mid price[30] of all the bonds and notes traded that day, the time to maturity, the settlement date, the coupon payments and the day counting market conventions. Moreover, the dataset provides information about the accrued interest and the modified duration. When these two quantities were missing, they were computed using the closing mid price. The dataset includes from 58 to 68 securities per day and covers a wide range of

[27] RRs that for calendar reason are made on the same day of the ordinary auction are not considered.
[28] For a review and assessment on the functioning and liquidity of MTS Italy market, see Coluzzi, Ginebri and Turco (2008).
[29] For further details on MTS Time Series, see Dufour and Skinner (2004).
[30] These are based on the average of best bid/offer prices at or before 5 p.m. CET.

maturities.[31] In particular the sample comprises 3-6-month and 1-year BOTs, 2-year CTZs, and 3-5-10-15-30-year BTPs. The bonds are ordered by quote date and then by maturity date. Intra-day data at a 5-minute frequency are used, instead, to work out the mispricing between the primary and the secondary market.

3.2 Calibration results

I estimate the model parameters through the non-linear least squares method by cross-section on each day in the sample.[32] Thus, the parameters are assumed to be constant over time in the derivation of the equilibrium pricing model. This is consistent with the assumption of taking the Specialist viewpoint. Indeed, this approach is similar to standard practice among option traders, who re-estimate volatilities every day or use implicit standard deviations as a basis for trading although their pricing model assumes constant volatilities.[33]

Table 3.1 compares the results of the calibration exercise with BCZ (1991) and Bernaschi, Torosantucci and Uboldi (2007), BTU. It is worth noting the reduction in the volatility and in the short rate over time. In particular, while the instantaneous interest rate is above 11% in the second part of the 80's[34], the present calibration of the CIR model produces an average instantaneous interest rate of 1.79% in 2004 and 1.95% in 2005. These figures are close to the average values of the 1-month, 2-month and 3-month Euribor rates, which values range over the same period are, respectively, 2.08%-2.14%, 2.09%-2.16% and 2.1%-2.18%. In addition, in the period under analysis the instantaneous interest rate displays a correlation of 83% with the 1-month, 90% with the 2-month and about 94% with the 3-month Euribor rates.[35] This is an index of the goodness of the model. Consistently, the model volatilities decrease along with interest rates. Since the model, on average, tends to underestimate the short term rate, it might be expected that, on average, the theoretical prices are higher than the market prices.

[31] On average the bond maturities range about from 23 days to 30 years.
[32] The calibration starting points are chosen through a stochastic multi-start method, see Appendix.
[33] Sercu and Wu (1997).
[34] Note that in that period the Bank of Italy official rate was above 10%.
[35] Source: elaboration on daily data from Reuters. The correlation coefficients are significant at the 5% level.

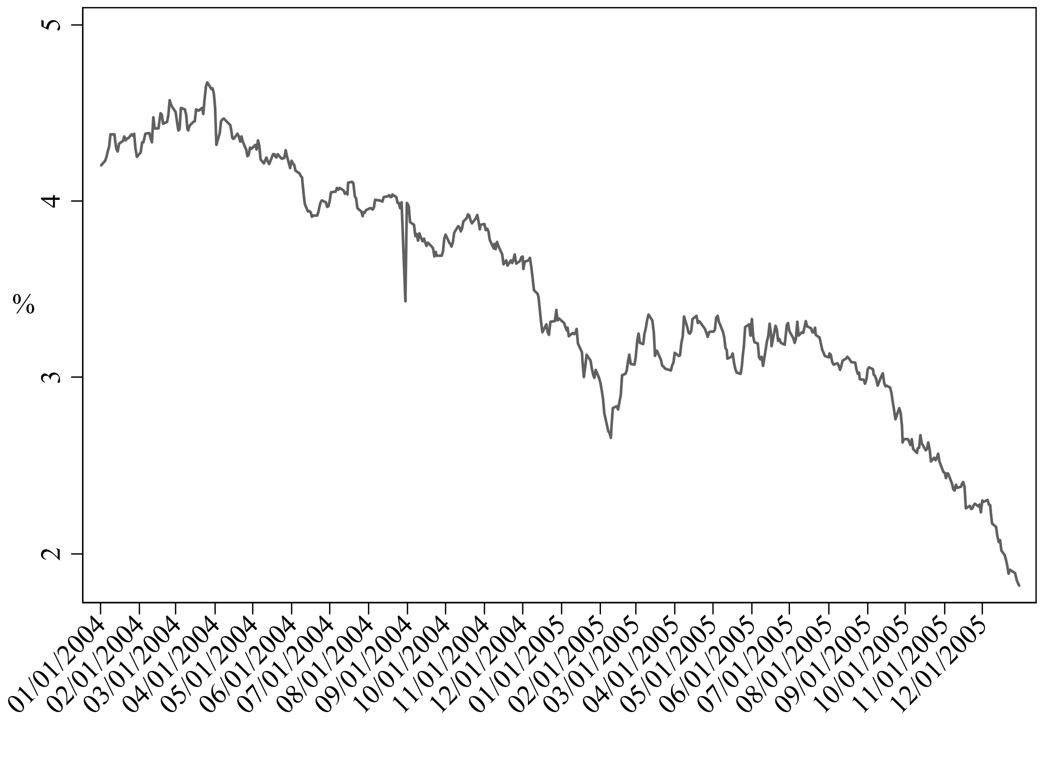
Table 3.1 CIR parameters

	BCZ (1984 - 1989)		BTU (1999 - 2000)		Coluzzi (2004 - 2005)	
	Mean	SD	Mean	SD	Mean	SD
ϕ_1	0.2509	0.0010	–	–	0.2096	0.0350
ϕ_2	0.2512	0.0010	–	–	0.1967	0.0338
ϕ_3	14.271	2.8197	–	–	4.6486	2.3294
r_t	11.519	3.156	4.232	0.421	1.8733	0.1920
κ	0.2433	0.0031	0.2804	0.1192	0.1839	0.0329
θ	11.128	1.8023	7.4701	1.2304	5.7512	0.6021
$\sigma\sqrt{r_t}$	2.1	0.3321	0.8098	0.3753	0.0956	0.0160

Note: The short term rate, r_t, and the long run expected value of the instantaneous interest rate, θ, are in %. The speed of adjustment, κ, and θ are worked out under the assumption that the market price of risk is zero. BCZ data source is the Milan Stock Exchange and the Wire Market from 30 December 1983 to 13 March 1989, BTU data source is Thomson Financial Datastream from November 1999 to November 2000.

Figure 3.1 shows the daily pattern of the term structure slope. This is computed as the difference between the asymptotic and the instantaneous interest rates. The figures are always positive in the period under analysis, thus implying an upward sloping term structure.

Figure 3.1 Slope of the term structure of interest rates



Note: The figure shows the pattern of the difference between the asymptotic and the instantaneous interest rates.

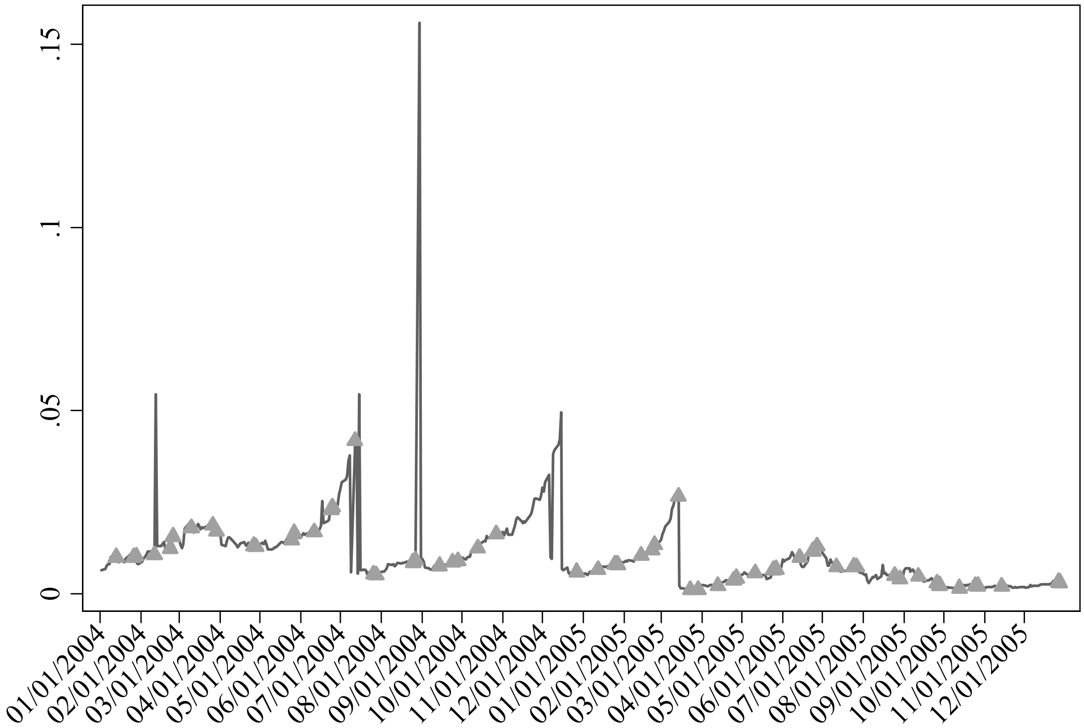
Another measure of the goodness of fit of the model is given by the sum of squared errors[36], *sse*, which is defined as:

$$sse = \sum_{i=1}^{N} \left(V_i - V_i^*\right)^2 \qquad (27)$$

where N is the number of bonds in each cross-section. Figure 3.2 shows the evolution of the *sse*. The latter is of interest in that it shows some regularity in 2004. The highest peaks, i.e. the peaks in the last 5% of the *sse* distribution, occur mainly in the middle of the month, that is when the 5-year BTPs are auctioned. This tells us that during these particular days the theoretical prices generated by the CIR model are affected by a larger mispricing with respect to the market prices. This might be of concern for the issuer, since a correct pricing of GS is extremely important especially around auction days. Indeed, the secondary market prices play an important role for the formation of the price on the primary market. The triangles indicate the day before an auction takes place; as it will be explained in the following, these days provide the input parameters for the option pricing. Apart from two cases, these days seems not particularly affected by high values in the *sse*. However, some robustness check are conducted to ensure that the call pricing is not systematically affected by a poor model fitting.

[36] Recall that *sse* is the score function to be minimized in the one-stage approach.

Figure 3.2 Sum of squared errors

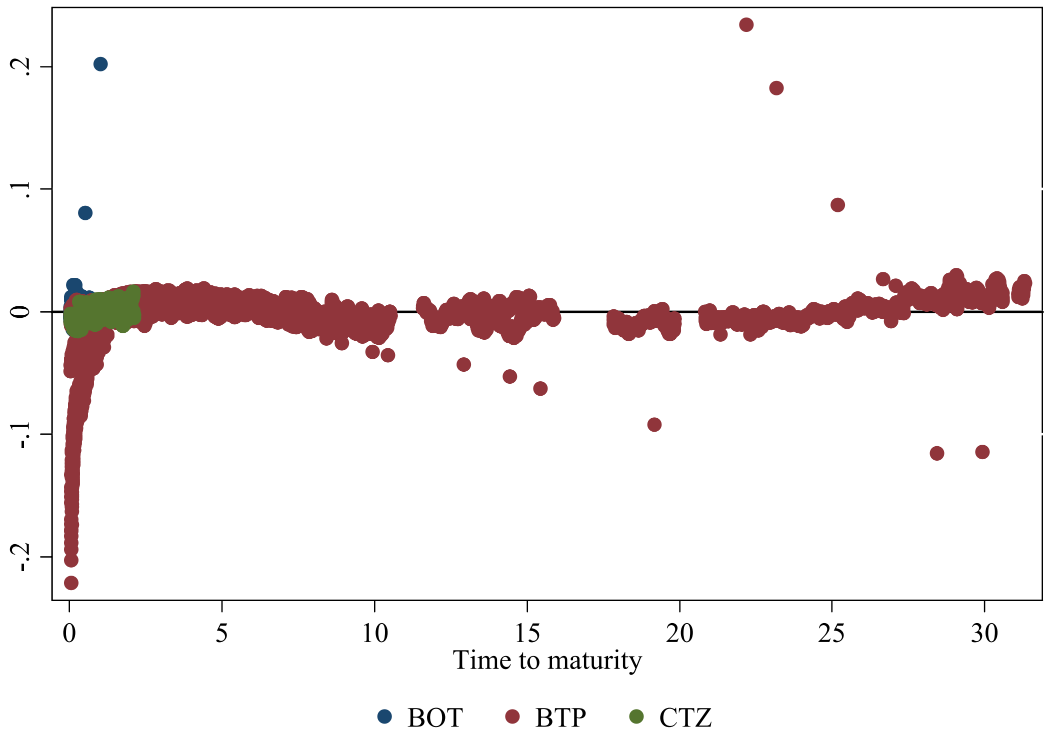


Note: The figure plots the daily sum of squared errors. Pricing errors are computed as the difference between the market and the model prices. The triangles indicate the *sse* in days that are input in the option pricing.

A common explanation for a poor model fitting performance is the inclusion of illiquid assets in the cross-section of GS. Figure 3.3 plots the residuals of the model computed as the difference between the market price, V, and the, theoretical price, V^*, against the bonds time to maturity. In general, theoretical prices are overvalued with respect to market prices, this is consistent with the fact that the short term interest rate is on average below the Euribor rates.[37] Mispricing is more evident for medium and long-term instruments, BTPs, as they approach their maturity. On the contrary, shorter term securities, BOTs, seldom show high mispricing. This is typically due to liquidity problems. In effect, it is reasonable to expect that short term GS are more actively traded, thus better priced, than longer-term BTPs. In effect, these latter GS are mainly retained in investors' portfolios as their maturity approaches. Some BTPs maturing in the next 15-30 years probably suffer as well from liquidity problems. This explain part of the peaks in the *sse*. In fact, the highest peak in figure 3.2 is largely due to the mispricing a 30-year BTP with 20 years to maturity. However, since some peaks occur around auction days, it is worth considering other sources of mispricing.

[37] See Table A.1 in the Appendix for summary statistics on pricing errors.

Figure 3.3 Model residuals



Note: The figure reports the plots of the model residuals computed as the difference between the market and the model prices. Time to maturity is in years.

For instance, it is interesting to verify if mispricing is affecting the model parameters because of Specialists behaving strategically to manipulate prices. Drudi and Massa (2005) show that informed dealers act strategically on the primary and secondary Italian GS markets. For the period 1994-1996 they provide evidence of price manipulation on the more transparent secondary market when the less transparent primary market is open. The peaks of mispricing around auction days could be a result of such a manipulation. As data disaggregated at the dealer level are not available here, it is not possible to perform a direct check. However, if manipulation occurs, one possible implication is that mispricing, and as a consequence high *sse*, are driven by the auctioned securities. Thus, we are able to check whether auctioned GS influence the CIR parameters when the primary market is open. An intuitive way to proceed is to calibrate the model excluding the auctioned securities. Accordingly, I selected the first day before the auction, the auction day and the RR day, then I eliminated the auctioned GS from each of the three days, and, finally, I calibrated again the CIR model. In principle, as each cross-section has a minimum of 58 GS and the maximum number of auctioned securities per day is 2, we may expect that only a huge price manipulation on this two GS could affect the model parameters. In effect, the improvement in the *sse*, after controlling for the number of securities, is small: the *sse* falls in 32% of the days in the sample, but the magnitude of the improvement is in the order of 10^{-6} and the mean difference is not statistically different from zero. It can be concluded that, in this sample, model fitting is not significantly affected by the auctioned securities.

The remaining question is the following: is it proper to delete from the database the securities that show high mispricing and calibrate again the parameters? Obviously, these "outliers" can produce a misleading term structure, but the market is also characterized by anomalous and relevant data, for instance due to liquidity problems.[38] Since it is assumed that the option pricing is considered from the point of view of a Specialist, no security is deleted from the sample.[39]

4 Option pricing

Given the parameters calibrated in the previous section, I can price the option implicitly granted by the Treasury to the Specialists using equation (25). From Assumption 1 follows that I have to rely on data that are the closer in time to the auction, thus I use the parameters calibrated on the business day that precedes the ordinary auction. The results of the option pricing are reported in Table 4.1. The first two columns contain a description of the auctioned bond, in particular if it is a coupon bond or a zero coupon bond, the maturity date, the coupon rate and the original maturity in years. The third column reports the date of the ordinary auction. Columns 4 to 9 include the four parameters resulting from the calibration of the CIR model, the volatility of changes in the instantaneous interest rate and the long run value of the instantaneous interest rate. The option's strike price and the option value are, respectively, in the last two columns.

[38] As for the benchmark studies, BCZ (1991) filter the data looking at the spread on return: if some bonds have spread on return greater than 2.57 times their standard deviation, the observation with greater spread on return is rejected and the regression to determine the model parameters is repeated. The rejection procedure is repeated recursively, until all outliers are erased. Bernaschi, Torosantucci and Uboldi (2007) do not delete any security.

[39] As a robustness check I calibrated the model and estimated the option value excluding, for each day, the two securities that exhibit the highest mispricing in absolute value. On average the option prices are only marginally affected.

Table 4.1 Option pricing results

Bond description	Original maturity	Auction date	ϕ_1	ϕ_2	ϕ_3	r_t	$\sigma\sqrt{r_t}$	θ	K	Option value
BTP 08/01/14 4,25%	10	1/29/2004	0.235	0.221	4.360	1.680	0.102	6.472	98.80	0.643
		2/26/2004	0.221	0.203	3.466	1.591	0.107	6.758	99.95	1.012
		3/30/2004	0.214	0.196	3.506	1.485	0.101	6.723	100.95	0.896
		4/29/2004	0.246	0.232	4.359	1.743	0.106	6.385	98.92	1.324
		5/28/2004	0.246	0.232	4.244	1.783	0.109	6.474	98.67	1.541
		6/28/2004	0.268	0.253	3.950	1.908	0.120	6.284	98.47	1.731
BTP 02/01/15 4,25%	10	8/30/2004	0.238	0.225	4.309	1.807	0.105	6.169	100.03	0.738
		9/29/2004	0.222	0.209	4.074	1.925	0.105	6.011	100.98	1.095
		10/28/2004	0.197	0.183	4.317	1.844	0.095	6.176	101.79	1.648
		1/28/2005	0.213	0.201	4.137	1.925	0.096	5.233	104.97	1.835
		2/25/2005	0.230	0.218	4.121	1.932	0.102	5.363	103.85	0.882
		3/30/2005	0.234	0.221	4.007	1.974	0.105	5.313	103.92	0.716
BTP 08/01/15 3,75%	10	4/28/2005	0.188	0.176	4.414	1.818	0.086	5.400	101.39	0.864
		5/30/2005	0.175	0.164	4.420	1.772	0.082	5.437	101.97	0.882
		6/28/2005	0.165	0.154	4.306	1.657	0.076	5.226	103.75	1.387
		7/28/2005	0.161	0.150	4.382	1.814	0.079	5.375	102.99	0.553
		8/30/2005	0.157	0.146	4.408	1.861	0.077	5.245	103.49	0.788
		9/29/2005	0.161	0.150	4.432	1.955	0.079	5.033	104.03	0.613
		10/28/2005	0.191	0.179	4.056	2.149	0.095	5.045	101.77	1.026
		12/29/2005	0.179	0.176	13.215	2.507	0.054	4.444	102.09	1.750
BTP 09/15/08 3,50%	5	1/14/2004	0.233	0.219	4.418	1.693	0.101	6.442	100.61	1.185
		2/12/2004	0.240	0.226	4.362	1.695	0.103	6.421	100.96	1.042
		3/11/2004	0.205	0.189	3.670	1.620	0.100	6.603	101.97	0.012
BTP 04/15/09 3,00%	5	5/13/2004	0.258	0.243	4.005	1.839	0.116	6.495	97.02	0.400
		6/14/2004	0.287	0.272	4.054	1.944	0.124	6.268	96.57	0.614
		7/13/2004	0.253	0.238	4.012	1.842	0.114	6.295	97.68	0.817
		9/15/2004	0.236	0.223	4.393	1.921	0.106	6.064	98.60	1.078
		10/14/2004	0.211	0.198	4.421	1.873	0.098	6.100	99.47	0.013
BTP 01/15/10 3,00%	5	1/13/2005	0.187	0.175	4.418	1.938	0.089	5.565	99.81	0.150
		2/15/2005	0.214	0.202	4.067	1.923	0.095	5.051	99.74	0.540
		3/15/2005	0.223	0.210	4.022	1.884	0.101	5.550	99.74	0.358
		4/14/2005	0.189	0.177	4.421	1.886	0.088	5.497	100.34	0.494
		5/12/2005	0.183	0.172	4.416	1.782	0.083	5.296	101.10	0.708
BTP 06/15/10 2,75%	5	6/15/2005	0.169	0.158	4.354	1.712	0.078	5.330	100.27	0.027
		7/13/2005	0.162	0.151	4.393	1.786	0.079	5.453	100.04	0.167
		9/13/2005	0.151	0.140	4.420	1.858	0.076	5.282	100.44	0.424
		10/14/2005	0.175	0.164	4.420	2.056	0.085	5.059	99.56	0.687
		11/15/2005	0.224	0.220	11.546	2.286	0.064	4.752	98.26	1.044

Table 4.1 (*continued*)

Bond description	Original maturity	Auction date	ϕ_1	ϕ_2	ϕ_3	r_t	$\sigma\sqrt{r_t}$	θ	K	Option value
BTP 01/15/07 2,75%	3	1/14/2004	0.233	0.219	4.418	1.693	0.101	6.442	99.72	0.032
		1/29/2004	0.235	0.221	4.360	1.680	0.102	6.472	99.57	0.180
		2/26/2004	0.221	0.203	3.466	1.591	0.107	6.758	100.27	0.117
		3/30/2004	0.214	0.196	3.506	1.485	0.101	6.723	100.75	0.237
		4/29/2004	0.246	0.232	4.359	1.743	0.106	6.385	99.76	0.689
BTP 06/01/07 3,00%	3	5/28/2004	0.246	0.232	4.244	1.783	0.109	6.474	100.07	0.039
		6/28/2004	0.268	0.253	3.950	1.908	0.120	6.284	99.77	0.181
		7/29/2004	0.286	0.271	4.104	1.873	0.120	6.131	99.86	0.342
		8/30/2004	0.238	0.225	4.309	1.807	0.105	6.169	100.52	0.600
		9/29/2004	0.222	0.209	4.074	1.925	0.105	6.011	100.52	0.921
BTP 02/01/08 2,75%	3	1/28/2005	0.213	0.201	4.137	1.925	0.096	5.233	100.25	0.021
		2/25/2005	0.230	0.218	4.121	1.932	0.102	5.363	100.02	0.123
		3/30/2005	0.234	0.221	4.007	1.974	0.105	5.313	99.96	0.356
		4/28/2005	0.188	0.176	4.414	1.818	0.086	5.400	100.77	0.487
		5/30/2005	0.175	0.164	4.420	1.772	0.082	5.437	100.99	0.733
BTP 06/15/08 2,5%	3	6/28/2005	0.165	0.154	4.306	1.657	0.076	5.226	100.75	0.001
		7/28/2005	0.161	0.150	4.382	1.814	0.079	5.375	100.29	0.091
		8/30/2005	0.157	0.146	4.408	1.861	0.077	5.245	100.24	0.386
		9/29/2005	0.161	0.150	4.432	1.955	0.079	5.033	100.13	0.571
		10/28/2005	0.191	0.179	4.056	2.149	0.095	5.045	99.41	0.900
		12/29/2005	0.179	0.176	13.215	2.507	0.054	4.444	98.91	0.289
CTZ 08/31/05	2	1/27/2004	0.239	0.225	4.302	1.677	0.103	6.462	96.39	0.000
		2/24/2004	0.225	0.211	4.310	1.675	0.100	6.568	96.72	0.000
CTZ 04/28/06	2	3/29/2004	0.205	0.188	3.452	1.440	0.098	6.755	95.56	0.000
		4/27/2004	0.245	0.231	4.279	1.717	0.106	6.401	95.10	0.002
		5/26/2004	0.260	0.246	4.107	1.822	0.115	6.455	95.09	0.003
		6/25/2004	0.262	0.247	4.065	1.913	0.117	6.275	95.26	0.004
CTZ 07/31/06	2	7/27/2004	0.280	0.266	4.101	1.860	0.118	6.129	94.64	0.032
		8/26/2004	0.237	0.224	4.371	1.815	0.104	6.172	95.25	0.005
		9/27/2004	0.228	0.215	4.409	1.933	0.103	5.980	95.43	0.004
		12/28/2004	0.184	0.172	4.416	1.938	0.089	5.651	96.36	0.000
		1/26/2005	0.200	0.189	4.425	1.907	0.090	5.268	96.63	0.000
		2/23/2005	0.232	0.220	4.126	1.937	0.101	5.265	96.73	0.000
CTZ 04/30/07	2	3/24/2005	0.240	0.227	4.007	1.965	0.106	5.322	94.73	0.017
		4/26/2005	0.185	0.173	4.412	1.835	0.086	5.475	95.47	0.000
		5/26/2005	0.179	0.168	4.408	1.783	0.082	5.244	95.88	0.000
		6/27/2005	0.168	0.157	4.197	1.666	0.078	5.253	96.32	0.000
		7/26/2005	0.159	0.148	4.356	1.793	0.078	5.443	96.22	0.010
		8/26/2005	0.157	0.146	4.377	1.834	0.077	5.262	96.41	0.005
CTZ 09/28/07	2	9/27/2005	0.155	0.145	4.437	1.925	0.077	5.132	95.46	0.025
		10/26/2005	0.185	0.174	4.436	2.110	0.088	4.936	95.21	0.088
		12/28/2005	0.183	0.180	12.695	2.515	0.056	4.492	95.15	0.089

Note: The original maturity is expressed in years. The CIR parameters are calibrated on the business day that precedes the auction. The option value is computed for a security of face value equal to 100. The instantaneous and the long run interest rates are in %. The latter, θ, is worked out under the assumption that the market price of risk is zero.

Table 4.2 reports summary statistics for the option value. The table shows that this is significantly different from zero. Such a result is not trivial, since the option lasts one day only and its value is an increasing function of its time to expiration (Cox, Ingersoll and Ross, 1985).[40] Both in mean and in median, the option value is increasing in the original maturity of the bond. This is probably due to the fact that long term bonds pay, on average, higher coupons for a higher number of cash flows. Longstaff (1993) analyses comparative statics properties of call and put prices in the CIR framework. The author finds that coupon bond call values are increasing functions of coupon size. The intuition is that an increase in the cash flows size increases the value of the underlying asset, and has a corresponding effect on option values. Call values reported in table 4.1 are on average increasing in coupon size both for 5 and 10-year BTPs.[41] Moreover, the call value is higher for BTPs than for CTZs.[42]

Table 4.2 Summary statistics

Bond type	N	Mean	SD	Median	95% Conf. Interval	
10-year BTP	20	1.096	0.418	0.954	0.901	1.292
5-year BTP	18	0.542	0.385	0.517	0.351	0.734
3-year BTP	21	0.347	0.291	0.289	0.215	0.480
CTZ 24m	21	0.014	0.026	0.003	0.001	0.026

Note: The table reports summary statistics for the option value aggregated by bond type.

5 The mispricing between the primary and the secondary GS markets

In the previous section, I found that the option implicitly granted by the Italian Treasury has value that is different from zero. In this section, instead, I rely on a subsample of the estimated option prices to discuss the value of the option in terms of the complex interplay between the issuer and the Specialists. The pricing of this privilege may be useful in evaluating the visible effect of this interplay, the so called *mispricing*. Note that now mispricing is not referred to as the difference between theoretical and market prices. On the contrary, there is mispricing when the prices at which GS are sold in auction are higher (*overpricing*, see Pacini, 2007) or lower (*underpricing*, see Drudi and Massa, 2005; Scalia, 1998; and Pacini, 2006) than the when-issued or secondary market prices. While underpricing is interpreted as a reward for the Specialists intermediation activity between the primary and

[40] Longstaff (1993) shows that the value of the call in the CIR framework is increasing in the time to expiration only if this is large enough.

[41] This result also holds if we consider median values.

[42] Other comparative statics properties include the call value being a decreasing function of strike price, coupon payment date and riskless interest rate, and an increasing functions of σ^2. Since these parameters change altogether over the sample, it is not possible to investigate these implications.

the secondary markets, overpricing might generate money losses in Specialists' balance sheet. This is particularly likely when Specialists have not a final customer for the auctioned GS.

The mispricing between the primary and the secondary market of GS is detected in different countries. Goldreich (2007) documents underpricing in the US Treasury bonds market over the period 1991-2000. Keloharju, Nyborg and Rydqvist (2005) measure underpricing in Finland for the period 1992-1999. They also survey underpricing in Treasury auctions in US, Mexico and Japan. Pacini (2007) finds significant overpricing in eurozone countries.

Since Specialists get almost the entire auction, the sign of mispricing presumably depends on the system of obligations and privileges set by the Treasury. For instance, overpricing can be partially explained by Specialists aggressive behaviour during the auction in order to obtain the right to participate in other special issues. Thus, the quantitative measurement of such obligations and privileges, in terms of costs and profits, is necessary in order to make a complete assessment of the whole placement mechanism. The pricing of the option implicit in the RRs is part of this assessment.

Table 5.1 reports a comparison between mispricing and the value of the option.[43] The third column reports the tranche of issuance; this is made of two numbers because the RR is counted as a new tranche issued of the same bond, therefore the first number refers to the ordinary auction and the second to the corresponding RR. Mispricing is computed as the difference between the price of the security on the primary market, i.e. the marginal price minus the placement fee, and the price on the secondary market on the auction day. In particular, the price on the secondary market is computed as the average of the best bid prices registered at a 5 minute frequency on MTS Italy between 10.25 a.m. and 10.55 a.m.. I use the bid price because this is the price a Specialist would offer to pay in order to buy the security on the secondary market.[44] The difference is almost always positive, hence supporting previous findings.[45] The question of interest is: does the option value account for part of these costs from overpricing? In other words, do the benefits coming from the positive value of the option explain (at least partially), the costs from overpricing? In order to answer, the overall benefit from the option, column 8, is computed as the product between the option value and

[43] The options on GS whose secondary price is not available in the dataset are excluded from the sample.
[44] Goldreich (2007) observes that the most relevant measure of mispricing is relative to the quoted bid, because it measures the different performance of Treasury and Specialist as sellers of GS.
[45] The magnitude and sign of mispricing depend on the measurement procedure. Pacini (2007) measures mispricing over different time periods. He always finds a significantly positive mispricing for Italy.

the number of bonds offered[46] in the RR. At the same time, the cost from overpricing, column 9, is the product between the amount issued in the ordinary auction and mispricing. It turns out that, for the longest maturities, the benefits often outweigh the costs. For CTZs, instead, this is never the case.

Table 5.1 Option value and the mispricing phenomenon

Bond description	Original maturity	Auction date	Tranche	Strike price	Option value	Mispricing	Option benefit	Cost of mispr
BTP 08/01/14 4,25%	10	1/29/2004	1_2	98.8	0.643	0.08	6.43	3.20
		2/26/2004	3_4	99.95	1.012	0.12	3.04	3.60
		3/30/2004	5_6	100.95	0.896	0.15	2.69	4.50
		4/29/2004	7_8	98.92	1.324	0.13	3.97	3.90
		5/28/2004	9_10	98.67	1.541	0.13	4.62	3.90
		6/28/2004	11_12	98.47	1.731	0.14	5.19	4.20
BTP 02/01/15 4,25%	10	8/30/2004	1_2	100.03	0.738	0.18	7.38	7.20
		9/29/2004	3_4	100.98	1.095	0.09	2.74	2.25
		10/28/2004	5_6	101.79	1.648	0.16	3.71	3.60
		1/28/2005	9_10	104.97	1.835	0.10	5.51	3.00
		2/25/2005	11_12	103.85	0.882	0.14	2.20	3.50
		3/30/2005	13_14	103.92	0.716	0.17	1.79	4.25
BTP 08/01/15 3,75%	10	4/28/2005	1_2	101.39	0.864	0.11	8.64	4.40
		6/28/2005	5_6	103.75	1.387	0.07	3.47	1.75
		7/28/2005	7_8	102.99	0.553	0.08	1.38	2.00
		8/30/2005	9_10	103.49	0.788	0.12	1.97	3.00
		9/29/2005	11_12	104.03	0.613	0.13	1.53	3.25
		10/28/2005	13_14	101.77	1.026	0.15	2.05	3.00
		12/29/2005	15_16	102.09	1.750	0.03	4.38	0.75
BTP 09/15/08 3,50%	5	1/14/2004	7_8	100.61	1.185	0.06	2.96	1.50
		3/11/2004	11_12	101.97	0.012	0.09	0.03	2.70
BTP 04/15/09 3,00%	5	5/13/2004	3_4	97.02	0.400	0.04	1.00	1.00
		6/14/2004	5_6	96.57	0.614	-0.11	1.53	-2.75
		7/13/2004	7_8	97.68	0.817	0.07	2.04	1.75
		9/15/2004	9_10	98.6	1.078	0.10	2.16	2.00
		10/14/2004	11_12	99.47	0.013	0.09	0.03	1.80
BTP 01/15/10 3,00%	5	1/13/2005	1_2	99.81	0.150	0.05	1.50	2.00
		2/15/2005	3_4	99.74	0.540	-0.34	1.76	-11.05
		3/15/2005	5_6	99.74	0.358	0.21	1.07	6.30
		4/14/2005	7_8	100.34	0.494	0.09	1.23	2.25
		5/12/2005	9_10	101.1	0.708	0.09	1.42	1.80
BTP 06/15/10 2,75%	5	6/15/2005	1_2	100.27	0.027	0.07	0.27	2.80
		7/13/2005	3_4	100.04	0.167	0.07	0.42	1.75
		9/13/2005	5_6	100.44	0.424	0.08	1.27	2.40
		10/14/2005	7_8	99.56	0.687	0.08	1.37	1.60
		11/15/2005	9_10	98.26	1.044	0.08	1.57	1.20

[46] As mentioned before, this number is equal to 25% of the amount issued in the ordinary auction if this is the first tranche, and 10% for the following RRs.

Table 5.1 (*continued*)

Bond description	Original maturity	Auction date	Tranche	Strike price	Option value	Mispricing	Option benefit	Cost of mispr
BTP 01/15/07 2,75%	3	1/14/2004	1_2	99.72	0.032	0.04	0.32	1.60
		1/29/2004	3_4	99.57	0.180	0.05	0.45	1.25
		2/26/2004	5_6	100.27	0.117	0.05	0.35	1.50
		3/30/2004	7_8	100.75	0.237	0.06	0.83	2.10
		4/29/2004	9_10	99.76	0.689	0.05	2.07	1.50
BTP 06/01/07 3,00%	3	5/28/2004	1_2	100.07	0.039	0.05	0.39	2.00
		6/28/2004	3_4	99.77	0.181	0.05	0.54	1.50
		7/29/2004	5_6	99.86	0.342	0.07	0.68	1.40
		8/30/2004	7_8	100.52	0.600	0.07	1.50	1.75
		9/29/2004	9_10	100.52	0.921	0.06	1.84	1.20
BTP 02/01/08 2,75%	3	1/28/2005	1_2	100.25	0.021	0.05	0.21	2.00
		2/25/2005	3_4	100.02	0.123	0.06	0.37	1.80
		3/30/2005	5_6	99.96	0.356	0.05	1.07	1.50
		4/28/2005	7_8	100.77	0.487	0.05	1.22	1.25
BTP 06/15/08 2,5%	3	6/28/2005	1_2	100.75	0.001	0.04	0.01	1.60
		7/28/2005	3_4	100.29	0.091	0.03	0.27	0.90
		8/30/2005	5_6	100.24	0.386	0.04	0.96	1.00
		9/29/2005	7_8	100.13	0.571	0.05	1.57	1.38
		10/28/2005	9_10	99.41	0.900	0.05	1.80	1.00
		12/29/2005	11_12	98.91	0.289	0.01	0.87	0.30
CTZ 08/31/05	2	1/27/2004	9_10	96.39	0.000	0.02	0.00	0.40
		2/24/2004	11_12	96.72	0.000	0.02	0.00	0.50
CTZ 04/28/06	2	3/29/2004	1_2	95.56	0.000	0.02	0.00	0.80
		4/27/2004	3_4	95.1	0.002	0.01	0.01	0.30
		5/26/2004	5_6	95.09	0.003	0.01	0.01	0.20
		6/25/2004	7_8	95.26	0.004	0.01	0.01	0.30
CTZ 07/31/06	2	7/27/2004	1_2	94.64	0.032	0.02	0.24	0.60
		8/26/2004	3_4	95.25	0.005	0.02	0.01	0.50
		9/27/2004	5_6	95.43	0.004	0.02	0.01	0.40
		12/28/2004	7_8	96.36	0.000	0.02	0.00	0.40
		1/26/2005	9_10	96.63	0.000	0.02	0.00	0.30
		2/23/2005	10_11	96.73	0.000	0.03	0.00	0.45
CTZ 04/30/07	2	3/24/2005	1_2	94.73	0.017	0.03	0.13	0.90
		4/26/2005	3_4	95.47	0.000	0.03	0.00	0.60
		6/27/2005	7_8	96.32	0.000	0.02	0.00	0.40
		7/26/2005	9_10	96.22	0.010	0.03	0.02	0.60
		8/26/2005	10_11	96.41	0.005	0.02	0.01	0.40
CTZ 09/28/07	2	9/27/2005	1_2	95.46	0.025	0.03	0.18	0.90
		10/26/2005	3_4	95.21	0.088	0.03	0.18	0.60

Note: The original maturity is expressed in years. The option value is computed for a security of face value equal to 100. The issued amount, the cost of mispricing and the benefit from the option are in millions of euro. Mispricing is in euros.

In Table 5.2 I collect the results by bond type. Apart from the costs of overpricing for the 5-year BTPs, costs and benefits are statistically different from zero at the 5% level. Interestingly, on average the advantages from the option outweigh the costs of overpricing for 5 and 10-year coupon bonds. For zero coupon bonds, instead, the advantages from the RR are well below the costs of overpricing. Since the mean values might be affected by outliers either in the option or in the mispricing valuations, median values are also reported. When considering the median values, the costs from mispricing are always above the option benefits. It can be concluded that the option implicitly granted to the Specialists is able to compensate, at least partially, the costs coming from aggressive bidding in the ordinary auction. In particular, for 10 and 5-year BTPs the median benefit from the option value is above 75% of the cost from overpricing. This figure falls to about 50% for 3-year BTPs and it is only 1.4% for CTZs. Since Specialists participate in the auctions for all the GS in the sample, overall in median about 72% of the costs from overpricing are compensated by the option value.

Table 5.2 Summary statistics

Bond type	N		Option benefit	Cost of mispricing	Median coverage
10-year BTP	19	*mean*	3.83	3.43	99.08%
		median	3.47	3.50	
		st. dev.	2.06	1.34	
		total	72.68	65.25	
5-year BTP	17	*mean*	1.27	1.12	76.32%
		median	1.37	1.80	
		st. dev.	0.78	3.55	
		total	21.63	19.05	
3-year BTP	20	*mean*	0.87	1.43	50.46%
		median	0.76	1.50	
		st. dev.	0.62	0.43	
		total	17.33	28.52	
CTZ	19	*mean*	0.04	0.50	1.40%
		median	0.01	0.45	
		st. dev.	0.08	0.20	
		total	0.81	9.55	
TOT	75	*mean*	1.50	1.63	71.26%
		median	1.07	1.50	
		st. dev.	1.82	2.11	
		total	112.45	122.37	

Note: The table reports summary statistics on option benefits and overpricing costs. The last row reports aggregate figures. Costs and benefits are in mlns of euros.

It is important to stress that this comparison between costs and benefits is somehow theoretical. Indeed, as showed in Table 2.1, not always the RR right is exercised. In the period under analysis only one third of the quantity offered in the RR was allotted. Interestingly, the bond segments with higher option value are not only the segments where the costs are balanced for a larger part by the option benefit, but also the segments whose RR total exercise rate is higher. Therefore, the Specialists recognize the option value, but this is only partially exploited. However, the RR is not the only privilege accorded to Specialists. Indeed, as long as the RR is accorded to all the Specialists, some of them also profit from other highly remunerative privileges.[47] Thus, Specialists, as a whole, profit from their status. These findings indicate that the disadvantages coming from the overpricing phenomenon are played down by the system of privileges accorded to Specialists. In addition, the benefits for Specialists are further amplified in the measure that the costs of overpricing are borne by the final customers.

6 Conclusions

A number of obligations and privileges are attached to the status of Specialist in GS. This paper focused on a major privilege that has received scant attention by the academic literature, namely the right to participate in the reserved auction reopening the day after the ordinary auction takes place. I modeled this privilege as a plain vanilla European call option written by the Treasury on the auctioned bonds. I chose the one-factor time-homogeneous version the Cox-Ingersoll-Ross model. This model guarantees positive interest rates and closed form solutions for bond and option on bond prices.

The first part of the paper was dedicated to the output of the model calibration. The non-linear least squares method was adopted to calibrate the model on the cross-section of all the trading days in years 2004-2005. The goal was to assess its performance and provide a comparison with previous studies on Italian data. Robustness checks guarantee that both computational issues, and strategic behaviour by market participants on auction days, do not strongly affect the performance of the model in fitting the current term structure of interest rates.

In the second part of the paper, I worked out the option value, and I related it to the mispricing phenomenon. It turns out that, although the short life, the option has a value significantly different from zero for each kind of security. This value is higher for coupon bonds with respect to zero coupon bonds and it is increasing in the original maturity of the security. Moreover, the option value helps in explaining the overpricing occurring between

[47] Pacini (2007) provides an estimate of the benefits coming from the admission of highly ranked Specialists to syndicated placements. He finds that for Italy in 2004 about 60% of the total costs of overpricing are covered by the profits from participating in syndicated issues. This result is particularly remarkable, as it is generated by 6 syndications only.

the primary and secondary markets. Indeed, the cost-benefit analysis showed that the benefits from the option cover, in median, 70% of the costs from aggressive bidding on the primary market. For coupon bonds with longer maturities the option value covers in median more than 99% of these costs. For zero coupon bonds this figure falls to about 1.4%. In general, the segments characterized by higher option value experience higher RR exercise rate. The reverse is true for CTZs, whose option value is close to zero and it is less exercised. In addition, if we also consider the revenues from participation in syndicated operations (as computed in Pacini, 2007), the disadvantages coming from the overpricing phenomenon are played down to a large extent by the system of privileges accorded to Specialists.

However, only one third of the quantity offered in RR over the sample period is allotted. Therefore, even though Specialists are aware of the option value, it can be concluded that this is only partially exploited. Assuming an interest of the Treasury in increasing the option exercise rate, for instance to increase the outstanding of a new issue, a policy implication might be to create a market for these options, i.e. to allow Specialists to sell their privilege. On the contrary, the Treasury could assign this benefit only to highly ranked Specialists in order to foster competition on the primary market.

The present analysis can be extended in different directions. First of all, a different choice for the term structure of interest rates model can be implemented.[48] In particular, it might be interesting to see if adding factors helps in improving the fit of the model. This comes at the cost that the Jamshidian (1989) result can no longer be applied, thus the price for options on coupon bonds should be evaluated numerically. Another extension would be the use of a model that ensures the perfect fit of the initial term structure. However, this might be difficult to calibrate with the Italian data available. Secondly, a natural extension of this research is a cross-country analysis. Indeed, the procedure here developed for the RR privilege easily extends to other countries with analogous primary dealer system (for eurozone countries see Bagella et al., 2007). This could be also appealing for the analysis of the mispricing between the primary and the secondary GS markets, which is a widespread phenomenon, too.

[48] Preliminary analysis in the Vasicek framework shows that the prices of call options written on 10-year BTPs are on average the same as in the CIR framework.

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APPENDIX: Parameters Calibration

The model is calibrated to the available data using a non-linear least squares method. This is a numerical method that finds the minimum of a function in a recursive way, starting from a parameters' vector arbitrary chosen. From a geometrical point of view, this method can be thought as a path that, from a starting point, chooses the way that brings to the nearest deep valley down. However, it could be possible that the nearest deep valley is not the deepest valley, i.e. the non-linear least squares method could bring to a local minimum. Therefore, the choice of the starting point is very delicate. In general we do not know, neither approximately, where the global minimum lies. This means that, in general, we cannot choose a reasonable starting point for the parameters' vector sufficiently close to the minimum. A rough but efficient method to overcome this problem is the so called stochastic multi-start method. According to this method, one has to build a net of starting points, to calibrate the model using *n* sets of starting points from the grid, and then to chose the parameters that ensure both a reasonable expectation of the market, and the mathematical hypothesis of the CIR model. If more than one of such sets satisfies these requirements, we chose the set that minimize the score function. The main drawback of this method is the long time necessary to give a solution. For this reason one possibility is to apply this procedure on a few distant days, or to apply it just on the first day and then use that day's local minimum as starting point for the following day's calibration. However, with this last method, if at day *t* a strange and particular market situation occurs, it is reasonable to obtain an anomalous minimum parameter vector. This could also distort the calibration results for the following days.

Since per each day I have on average 62 securities, it should not be problematic to find the global minimum independently by the chosen starting point. Thus, I used a simple version of the stochastic multi-start method. First, I fixed an interval for each element of the parameter's vector. The intervals should be large enough to include the global minimum. In order to limit the dimension of the intervals I chose them in such a way that they include the values found in previous calibrations of the CIR model on Italian data.[49] Then, I made a draw of the first set of starting points from the uniform distributions functions built on the chosen intervals, and I calibrated the CIR model for all the days in the sample using the selected vector of starting points. I stored the result and I made a second draw and calibration. At the

[49] BCZ (1991) and BTU (2007).

end of the second simulation I compared the resulting minima with the previous ones. Finally, I saved the best parameters coming from this comparison into a separate file, where for best selection criterion I used, accordingly with the non-linear least squares method, the sum of squared errors. I repeated this procedure 100 times. The output was a file containing 101 different values for each parameter on each day and a file including the time series of the best set of parameters. This procedure allows each set of parameters to come from a different vector of starting points. In order to check for the stability of the obtained parameters, I also counted the number of revisions on parameters coming from the 101 simulations: these are on average 5. As a robustness check, I repeated this procedure 10,000 times on a single day. I had revisions only in 1% of the calibrations. Moreover, even when a revision occurred the change in the parameters was negligible.

Table A.1 reports summary statistics on pricing errors computed using the "optimal" set of parameters.

Table A.1 Summary statistics on bond pricing errors

Bond maturity	N	Mean	SD	Min	Max
2004	3006	-0.0092	0.0198	-0.2212	0.0808
2005	7414	-0.0058	0.0174	-0.2029	0.2018
2006	5448	0.0011	0.0065	-0.0220	0.0217
2007	3762	0.0040	0.0053	-0.0115	0.0182
2008	1917	0.0047	0.0051	-0.0116	0.0174
2009	1474	0.0053	0.0058	-0.0055	0.0191
2010	908	0.0053	0.0065	-0.0086	0.0158
2011	514	0.0005	0.0078	-0.0128	0.0135
2012	514	-0.0016	0.0087	-0.0164	0.0130
2013	1028	-0.0044	0.0080	-0.0259	0.0118
2014	497	-0.0077	0.0057	-0.0329	0.0097
2015	525	-0.0118	0.0056	-0.0356	0.0045
2017	514	-0.0015	0.0056	-0.0433	0.0110
2019	514	-0.0013	0.0074	-0.0528	0.0131
2020	460	-0.0067	0.0075	-0.0626	0.0055
2023	514	-0.0092	0.0056	-0.0921	0.0021
2026	514	-0.0059	0.0108	-0.0187	0.2341
2027	514	-0.0062	0.0085	-0.0185	0.1822
2029	514	-0.0014	0.0054	-0.0123	0.0871
2031	514	0.0030	0.0035	-0.0085	0.0265
2033	514	0.0092	0.0069	-0.1158	0.0189
2034	514	0.0158	0.0081	-0.1146	0.0298
2037	55	0.0180	0.0030	0.0105	0.0248

Note: Pricing errors are in euro for 100 euros of face value.

CHAPTER 3

MEASURING AND ANALYZING THE LIQUIDITY OF THE ITALIAN TREASURY SECURITY WHOLESALE SECONDARY MARKET[°]

With

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Abstract

Although its importance, only recently the issue of liquidity in Treasury markets has received greater attention. We survey the literature about market liquidity and liquidity measures, and we put forward new measures. The aim is to provide a description of the liquidity of the Italian wholesale secondary market, which we describe thoroughly. We apply a large set of measures on a unique dataset, which gives us a complete view of the market. We find that the quality of the order book seems to be low, and despite the presence of a large number of market makers, the degree of competition among them is not very high. Moreover, no clear and general relationship emerges between trading and order book measures. Indeed, even though trading activity is higher for *on-the-run* securities with respect to the *off-the-run* securities, there is not a sharp difference in terms of liquidity of the order book between them. In this case market regulation plays an important role. Finally, we investigate how long it takes for a new issue to become the benchmark for its segment. Our evidence shows that some modifications of the issuance policy in order to have a larger outstanding since the first auction could help securities in gaining earlier their benchmark status, especially in case of 10-year BTPs.

Keywords: Liquidity, liquidity measures, Government securities, market microstructure, benchmark status.

JEL Classification: D49, G12, H63.

[°] This paper relies on the final report of a research carried out by University of Molise and financed by Italian Ministry of the Economy and Finance, Department of the Treasury. Although this research has been conducted with the joint contribution of all the authors, Chiara Coluzzi and Segio Ginebri elaborated the empirical analysis and drafted the text, while Manuel Turco provided support about the data filtering procedure and the new developed measures. Chiara Coluzzi elaborated the main dataset as well. The authors acknowledge the valuable and constant support, advice and cooperation received by Italian Debt Management Office, Ministry of the Economy and Finance, Department of the Treasury, Directorate II, in particular, Davide Iacovoni, Paola Fabbri and Tiziana Capponi. We also would like to thank A. Dufour, C. Parlour, A. Scalia and the other participants at the XVI International Tor Vergata Conference on Banking and Finance, Rome, and at the Seminar "La liquidità del mercato secondario all'ingrosso dei titoli di stato italiani: recenti tendenze prima e dopo la crisi dei sub-prime", Department of the Treasury, Ministry of the Economy and Finance.

1. Introduction

In a liquid market the participants can rapidly execute large-volume transactions with small impact on prices (CGFS, 1999). Moreover, liquidity in Government securities (henceforth GS) markets allows market participants to hedge positions in other fixed income securities, to speculate on interest rates and to price correctly other securities such as derivatives on interest rates (Fleming, 2003). Hence, the measurement of liquidity is of relevance to those who transact in the market and to those who monitor and analyze market conditions and developments. Indeed, liquidity plays also an important role for financial stability and is a crucial point in monetary policy. Furthermore, it has a role in the determination of the security yield. Therefore, it can relevantly affect the cost of liability management, and Government debt management offices are highly concerned about the liquidity of GS markets. Despite its relevance, the concept of market liquidity can hardly be pinned down. Actually, it has multidimensional aspects and, consequently, many different definitions and measures of markets liquidity are available. Broadly we can distinguish trade measures and quote (or order book) measures. Trade measures draw from data on actual financial transactions. Quote measures, on the contrary, describe the characteristics of the proposals of transactions that are available in the market. Both measures are useful and they complement one another. Furthermore, their relevance in catching the various aspects of market liquidity depends on the microstructure of the market that is under examination. The present study focuses on MTS (*Mercato Telematico dei titoli di Stato*) Italy, which is an example of quote-driven electronic order book wholesale secondary market. Among the wholesale markets, MTS is the leading market in Europe for the electronic trading of fixed income securities. Within the MTS system the weight of Italian securities is prominent. The main aim of the present paper is to measure and evaluate the market liquidity of MTS Italy, by using a unique dataset. Our results are going to cast additional light on the liquidity issue, that has received limited attention in the literature[1]: exceptions are among others Albanesi and Rindi (1999), Cheung, de Jong and Rindi (2005) and Girardi and Piga (2007) for Euro area, Fleming (2002, 2003) and Fleming and Mizrach (2007) for US, and Kamara (1994), D'Souza, Gaa and Yang (2003), D'Souza and Gaa (2004) and Campbell and Hendry (2007) for Canada.

The main contributions of this paper are both institutional and empirical. Among the former we survey in detail a large set of measures, and we put forward new measures to best fit the data source available to us. In particular, we focus on the order book. The quality of the order book is

[1] In the last decade the major body of literature about market microstructure focused on equity and foreign exchange markets.

relevant, since the quotes on the book are firm and immediately executable. Therefore, the structure of the order book and its evolution in time define the amount of liquidity provided by the market makers. Our discussion of the liquidity measures is done according to the taxonomy tightness-depth-breadth. Where tightness, the first dimension, is about the distance between the ask and the bid side of the book, depth deals with the quantity available for trade on each side of the book, and breadth measures how wide the order book is. In addition, we provide an organic description of the MTS microstructure. From the empirical perspective, although mainly descriptive, we perform with different time horizons a liquidity comparison across measures, and we explore commonality in liquidity through a comparison across securities. This analysis allows us to select the indicators that best describe the liquidity of the market. The selection of our preferred measures follows the criteria specified in Fleming (2003): A liquidity measure should directly quantify the transaction costs, behave consistently with market participants' view about liquidity, be easy to calculate and be available on a real-time basis.

Best spread and best size turn up to be good indicators. Indeed, they behave consistently with the other liquidity indicators and are easily available. Indicators that combine two dimensions of the taxonomy are more time consuming in terms of computation, but provide important information on market liquidity. With respect to model based measures, our estimates of the price impact coefficient, as in Kyle (1985), add to a wide literature on the information content of the order flows (Cheung, de Jong and Rindi, 2005; Brandt and Kavajecz, 2004; Green, 2004; and Pasquariello and Vega, 2007).

The main advantage of our research is the availability of high frequency data on the whole order book. Our dataset covers transactions and quotes of the Italian medium and long term Government bonds being traded on the MTS Italy platform from January 2004 to December 2006. We mostly focus on medium and long term fixed coupon bonds (BTPs), which on December 2006 account for almost 60% of the outstanding securities. Data are provided by the Italian Treasury that collects them directly from the MTS Italy market. This data source is unique since it shows all the quotes and the relative quantities that are active on the market. The implication is that we are allowed to see the complete book (all the quotes and block quantities[2]). All the contracts are also available and they include the sign and the time of the trade. Transactions and quotes are available for both on-the-run and off-the-run securities, where for on-the-run we mean the most recently auctioned security. The availability of both kinds of data will permit us to understand when, in terms of liquidity, an on-the-run security becomes the reference for its maturity segment, i.e. the *benchmark*. Indeed, as a direct application of the analyzed measures, we contribute to the literature

[2] This is the total amount of the proposal, actually a participant may limit the display of his proposals to a partial amount, the drip quantity.

on benchmark analysis. In particular we evaluate, in terms of liquidity, when a new issue become the benchmark for its segment (Dunne, Moore and Portes, 2002; D'Souza, Gaa and Yang, 2003; Alonso et al., 2004). Our evidence suggests, as policy implication for the Treasury issuance strategy, that increasing the amount issued at the first auction could foster the achievement of the benchmark status.

Interestingly, we compare the values of the liquidity measures found on MTS with the values of the same measures on other platforms for analogous GS. Our yardsticks are one of the major Interdealer Broker electronic platforms in the U.S., BrokerTec, and the Canadian Interdealer Brokered market for Government bonds. Although less liquid than the US market, MTS Italy liquidity is well above Canadian market liquidity.

The rest of the paper is organized as follows: Section 2 surveys the literature on liquidity measures and definitions, section 3 introduces and discusses the liquidity measures employed in our analysis according to our taxonomy, section 4 presents the microstructure of MTS Italy market, section 5 states our research agenda and presents the data, section 6 illustrates the empirical results, section 7 analyses the achievement of the benchmark status by on-the-run securities, section 8 concludes.

2. Liquidity

A financial security is liquid if it can be traded in a market without significantly affecting its price. The measurement of liquidity is of relevance to those who transact in the market and to those who monitor and analyze market conditions and developments. In particular, it is a key issue for central bank functions, including the conduct of monetary policy and the maintenance of financial stability. The importance of liquidity in preserving the stability and efficiency of capital markets means that the role of public policy is fundamental. Regulations can help fostering higher-quality markets at little cost. Conversely, public policy can also harm the liquidity of markets. Therefore, the determinants and mechanics of liquidity in these markets deserve great attention. In effect, although in the last decade the major body of literature about market microstructure focused on equity and foreign exchange markets[3], now the strand of literature about liquidity in bond markets is growing in importance and this is also due to the recent availability of high frequency data[4]. Fleming (1997, 2001, and 2003) and Fleming and Mizrach (2007) for US, D'Sousa, Gaa and Yang (2003) for Canada and Cheung, de Jong and Rindi (2005) and Girardi and Piga (2007) for the Euro area measure liquidity and order flows in GS markets. Fleming and Remolona (1999), Bollerslev,

[3] Madhavan (2000) and Lyons (2001) survey respectively stock and forex markets.
[4] For instance GovPx for US, CanPx for Canada and MTS Time Series for Europe.

Cai and Song (2000), Balduzzi, Elton, and Green (2001), Green (2004) analyse price formation and liquidity in the US Treasury market by examining the response of prices, trading volume and bid-ask spreads to macroeconomic announcements. Pagano and von Thadden (2004) document the impact of EMU on the European Bond Market in terms of markets integration and liquidity, the consequent emergence of the MTS and Eurex markets and they discuss pros and cons of the "Liquidity Pact"[5].

2.1 Definitions

Market liquidity is a concept that turns out to be hard to pin down. It has multidimensional aspects and many definitions of markets liquidity are available. For instance, a liquid market can be defined as one in which trades can be executed without costs (O'Hara 1995); another definition states that in a liquid market the participants can rapidly execute large-volume transactions with small impact on prices (CGFS 1999). The usual approach that the market microstructure literature adopts (see for instance Kyle, 1985) is to think about liquidity along three possible dimensions: Tightness, depth and resiliency. *Tightness*[6] indicates how far transaction prices diverge from mid market prices (i.e. the cost of providing liquidity), *depth* is the maximal size of a trade for any given bid/ask spread (or the maximum volume of trades without a significant affection of prices) or the amount of orders on the order-book of market makers at a given time and *resiliency* refers to how quickly prices revert to original (or fundamental) levels after a large transaction (i.e. the speed with which price fluctuations resulting from a trade are dissipated). Another commonly used concept is *immediacy*, defined as the speed with which a trade of a given size at a given cost is completed. However, it incorporates elements of the dimensions listed above and, strictly speaking, it is not a separate dimension[7]. In what follows, along with tightness and depth, we will use *breadth*, which measure how wide the order book is, to discuss the liquidity measures.

2.2 Survey of liquidity measures

The analysis of market liquidity avails itself of different measures, the preference between one and another depending mainly on the goal of the analysis and data availability. Table 2.1 provides a survey of the most conventional measures, the first and the second column give a definition and some comments, the third column reports the expected relation with market liquidity. Moreover, the first column reports, between square brackets, alternative definitions for the same measure. As a matter of fact, the definition of many variables is often not unique, since the purpose

[5] From a theoretical point of view, Amihud and Mendelson (1986, 1991) and more recently Pastor and Stambaugh (2003) provide theoretical models explaining the role of liquidity in asset pricing and in government bond asset pricing.
[6] Sometimes in literature it is referred to as *width*.
[7] Sources of the definitions are CGFS (1999) and D'Souza and Gaa (2004).

of the analysis or data availability can differ. The measures reviewed in Table 2.1 range from general information about the securities (e.g. issued amount and age) and the market (e.g. number of participants, bid quantity etc.) to more complex indexes (e.g. percentage bid-ask spread, market quality index etc.). The table also permits to group the variables as trading variables, order book variables and other variables.

Table 2.1 Liquidity measures: definitions and comments

Definitions	Comments	Expected Relation to Liquidity
issued amount: the size of the issuance (Houweling et al., 2003).	The larger the outstanding stock of publicly issued central government debt, generally the higher the turnover in cash and futures trading. And the higher the turnover, the better the liquidity (McCauley and Remolona, 2000).	+
age: time from issuance (Houweling et al., 2003).	Important for instance because of the market segmentation for different asset maturity (Martinez and Resano, 2005)	–
missing prices: it occurs when the bond did not trade in a given interval of time.	If the price at the end of the day is identical to that of the previous day, it is highly likely the bond did not trade; likewise if there is a missing price (Houweling et al., 2003).	–
bid-ask spread: *quoted*: gap between quoted bid and ask prices, and is observed before an actual transaction takes place (CGFS, 1999).[difference between the best bid and the best ask at any time and averaged over all quotes in a day (Goldreich et al., 2005)] *realised*: gap between weighted averages of the bid and ask prices for executed trades over a period of time, using the transaction volumes at each price as the weights (CGFS, 1999). *effective*: twice the difference between each transaction price and the mid-quote immediately preceding the transaction (Goldreich et al., 2005 e Chung et al., 2005). [expressed as a percentage of the mid-quote based on the actual transaction	A drawback is that bid and offer quotes are good only for limited quantities and periods of time, thus it only measures the cost of executing a single trade of limited size. To allow for comparison between different securities it should be adjusted to take into account duration (Fleming, 2003). Wider spreads may also simply reflect that the bond in question is illiquid for structural, as opposed to market structure, reasons (Casey and Lannoo, 2005). It incorporates the change in the price between when it is quoted and when it is executed (CGFS, 1999).	–

price (Dunne et al., 2006)].		
percentage quoted spread: the average of the ratio of the quoted bid/ask spread to the bid/ask price midpoint (Bollen and Whaley, 1998). [using only two-sided quotes (Brandt and Kavajecz, 2004)]. *percentage effective spread*: dividing the dollar effective spread by the quote midpoint (Chung and Kimb, 2005)	It illustrates that spreads differ by the level of share price. Trading costs for low price per share stocks are higher.	–
volume weighted average quoted spread: the average of the quoted bid/ask spreads during the day weighted by the proportion of daily trading volume executed while each pair of quotes was in effect (Bollen and Whaley, 2005).	It is a measure of depth of the limit order book associated to a specific transaction size, it reflects the implicit cost for an immediate transaction of a given size (Cheung et al., 2005). It weights the prevailing quotes by the number of shares traded (as a proportion of total daily trading volume) while the quotes were in effect. Consequently, it is more accurate *a priori* since transactions at the prevailing quotes indicate that prices were "firm." (Boll and Whaley, 1998)	–
trade - weighted effective spread (Chung and Kimb, 2005)		–
price impact of trades: the difference between the effective and realized spreads. (Chung and Kimb, 2005)		–
quote size: the quantity of securities that is explicitly bid for or offered for sale at the posted bid and offer prices (Fleming, 2003).	It can underestimate depth because market makers usually do not reveal the full quantity they want to transact (Fleming 2003).	+
best liquidity: the average of the quoted size at the best bid and offer where considering the quotes immediately preceding the transactions (Dunne et al., 2006).		+
total liquidity: the average of the total amount offered and the total amount bid in the best three quotes where only including the quotes immediately preceding the trades (Dunne et al., 2006).		+
quote frequency: the number of non-repeated quotes in a time interval (D'Souza and Gaa, 2004).	It is a measure of market activity (D'Souza and Gaa, 2004).	+?
trade size: ex-post measure of the quantity of securities that can be traded at the bid or offer price (Fleming, 2003).	It is an endogenous measure because it depends on a negotiation that depends on the liquidity of the market (D'Souza and Gaa, 2004). Higher trade size is usually associated to low transparency	+?

	(Dunne et al., 2006)	
bid-side market depth: the difference between bid and mid price, divided by the bid quantity (Favero et al., 2005).		+
ask-side market depth: the difference between mid price and ask price, divided by the ask quantity (Favero et al., 2005).		+
quoted depth: the average of the bid and ask depth per quoted price, both one and two-sided quotes are used in the calculation (Brandt and Kavajecz, 2004).	A drawback of this estimate is that market makers often do not reveal the full quantities they are willing to transact at a given price, so it depth underestimates the true depth (Fleming, 2003).	+
cumulative limit order book depth: sum of the depth posted at the three best price points on both the buy and sell side of the limit order book and average the two sides together (Beber et al., 2007).		+
price impact coefficient (Kyle lambda): the slope of the line that relates the price change to trade size and is typically estimated by regressing price changes on net volume for intervals of fixed time (Fleming, 2003).	It is relevant to those executing large trades or a series of trades (Fleming, 2003). One drawback is that, although it necessitates the use of detailed high-frequency data, it is estimated over a longer sample period. The estimated price-impact coefficients therefore cannot be used directly in an analysis of intraday market conditions (D'Souza et al., 2003).	–
liquidity premium: "liquidity" spread between more and less liquid securities, often calculated as the difference between the yield of an on the-run security and that of an off-the-run security with similar cash flow characteristics (Fleming, 2003).	It can be calculated without high-frequency data. Moreover, as it reflects both the price of liquidity and differences in liquidity between securities, it provides insight into the value of liquidity not provided by the other measures. However, other factors can cause on-the-run securities to trade at a premium, confounding the interpretation, and the choice of an off-the-run benchmark can result in considerable estimation error (Fleming, 2003).	–
trading volume: the total value of securities traded per unit of time (D'Souza and Gaa, 2004).	It is positively related with price volatility which is negatively related to liquidity (Fleming, 2003).	?
trading frequency: the number of trades executed within a specified interval, without regard to trade size (Fleming, 2003).	It is positively related with price volatility which is negatively related to liquidity (Fleming, 2003).	?
price volatility	If we assume a constant fundamental level of prices, it could reflect bid-ask spread, the market impact of	–

	trades and/or the degree of resiliency (CGFS, 1999).	
turnover ratio: the ratio of the average trading volume over a given period of time to the outstanding volume of securities (CGFS, 1999).	If the Government or the central bank take a large portion of securities out of the market, we should account subtract such holding from the outstanding volume. (Inoue, 1999).	+
number of market participants in a given time interval		+
net trading quantity: the volume of buyer-initiated trades minus the volume of seller-initiated trades over the time interval (D'Souza and Gaa, 2004). *net trading count*: the number of buyer-initiated trades minus the number of seller-initiated trades over the time interval (D'Souza and Gaa, 2004).	Those are conventional measures of trading activity (D'Souza and Gaa, 2004).	–
order imbalance: notional value of buys less the notional value of sells each day, divided by the total value of buys and sells (Chordia and Sakar, 2005).		?
market quality index: the average quoted depth divided by the percentage bid-ask spread (Boll and Whaley, 1998, & Beber et al., 2007).	Index designed to capture the trade-off between quoted bid/ask spread and market depth (Boll and Whaley, 1998).	+
steepness: the average of steepness on each side of the order book. The steepness is the difference between the 3rd worst bid/offer and the best bid/offer expressed as a percentage of the mid-point between these, multiplied by 100 to show it in basis points terms (Dunne et al., 2006).		–
Cost of Round Trip trade (CRT): the percentage cost to buy and sell the same number of shares at the same time (a round-trip trade) by submitting market orders (Irvine et al., 2000). Cheung et al. (2005) give a formulation of CRT for the bond market.	It aggregates the status of the limit order book at any moment in time for a specific transaction size. It measures the ex ante committed liquidity immediately available in the market. Given a trade size, smaller cost indicates a more liquid market (Irvine et al., 2000).	–

Note: The question mark indicates that the expected relationship with liquidity is not univocal.

3. Liquidity Measures Under Examination

Given the survey of liquidity measures, in this section we present and explain in detail the measures we analyzed. In particular, we elaborate a taxonomy for the order book measures and according to this we present common and new liquidity indicators. Finally, we present and discuss trade measures.

3.1 Order book measures: A taxonomy

We classify order book measures according to three dimensions: *Tightness, depth* and *breadth*. The first dimension is about the distance between the ask and the bid side of the book. Tightness is the dimension whose connection with the meaning of liquidity is the clearest: The closer the two sides, the more liquid the market. A tight order book reduces the cost of successive buy and sell operations on the same security. The second dimension, depth, deals with the quantity available for trade on each side of the book. The relationship between depth and the concept of liquidity is clear as well: The deeper the order book the more liquid the market. However, in order to gauge market liquidity we need not only the simple measure of the quantity available for trade but also its position in the book. The third dimension, breadth, measures how wide the order book is. While depth captures the vertical dimension of each side of the order book, by measuring the quantitative relevance of each proposal, breadth catches the corresponding horizontal dimension by measuring the multiplicity, the variety among the proposals: "A broad market has many participants, none of whom is presumed to exert significant market power"[8]. Breath is the dimension of our classification whose relationship with the concept of liquidity is more controversial. According to some authors the narrower the order book, the more liquid a market[9]. In effect, when one side of the order book is as narrow as possible, that is when it is concentrated just in a quote, all the order book depth is available at the best quote and market liquidity is at maximum for that given level of depth. However, as long as the order book is not fully concentrated on the best quote, the relationship between breadth and liquidity becomes vaguer. A wide order book, where the quantity available for trade is mostly concentrated on the best price, is more liquid than an order book made of two adjacent prices, where the same quantity is mostly concentrated on the second best price. In our understanding, breadth has to be combined with depth in order to have a reliable measure of liquidity.

In the following we are going to present the order book measures we employed in the empirical analysis[10]. The measures are considered to be either unidimensional, when they evaluate just one of the three dimensions of our taxonomy, or multidimensional, when they are a combination of at least two dimensions. All the unidimensional measures are drawn from the wide

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[8] See Hasbrouck (2007). The breadth is strictly connected with market thickness, as defined in Roth (2007).
[9] See Dunne, Moore and Portes (2006).
[10] The complete set of the investigated measures includes also *midquote*, *percentage quoted spread*, *quantity weighted bid (ask) skewness*, *quantity weighted bid (ask) kurtosis*. The final set of measures has been worked out after an evaluation of all the measures in terms of univariate and correlation analysis.

literature surveyed above. On the contrary, some of the multidimensional measures are originally elaborated by us in order to exploit the richness of our dataset. Finally, we present measures of market conditions.

3.1.1 Tightness

The tightness of the order book is measured by spreads. We are going to use three different definitions of spread: best spread, spread and weighted spread. *Best spread* is the difference between the best ask price and best bid price[11]. It is the simplest measure of spread and it can be quickly and easily calculated with data that are widely available. However, it takes into account only one price on each side of the book and the quantity available for trade at the best prices could be very small. The whole set of quotes in any "snapshot" of the order book is included in the definitions of *spread* and *weighted spread*[12]. The former is the difference between the simple average of the ask prices and bid prices. The latter is the difference between the weighted averages, where the weights are given by the quantity available for trade at each quote. The last two measures give a more thorough view of the order book, but they cannot be as quickly and easily calculated as best spread is.

3.1.2 Depth

We employ several measures of depth. All the measures we are going to present hereafter are averages of the corresponding measures on the two sides of the order book as preliminary analyses showed the perfect symmetry between the two sides. *Quote size* is the total quantity available for trade at a given point in time[13]. Its value does not depend on the position of the quantity in the book. However, the degree of liquidity of a given amount of quantity for trade is strictly related to its position in the book. Thus we employ three other measures that split the total quote size in three parts according to the position of the quote quantity in the book: *Best size*, *second size* and *worst size*[14] measure respectively the quantity available at the best price, at the second best price and in the rest of the book. The rational behind this splitting is clear: If an increase of the depth is due to an increase of the quantity available for trade far from the top of the book, then quote size would overstate the actual market liquidity. Hence, a distinction between quote sizes on the top of the book and on the rest of it better captures the real depth of the market.

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[11] Appendix B provides the analytical formulation of the complete set of the employed measures. Best spread matches with the quoted bid-ask spread in Goldredich (2005).
[12] Spread and weighted spread match with the quoted bid-ask spread in CGFS (1999).
[13] Quote size matches the quote size in Fleming (2003) and it is close to both total liquidity in Dunne et al. (2006) and cumulative order book in Berber et al. (2006).
[14] Best liquidity matches with the best liquidity in Dunne et al. (2006). Second and worst size are not present in the papers we surveyed.

We also adopt synthetic measures of depth, that is we calculated some statistics of the quantity available for trade that could better captures the liquidity of the order book in each snapshot. *Average quote size* is the average quantity available for trade per quoted price[15]. It measures how dispersed the quote size is among different quotes. The higher the average quote size, the deeper the order book. Average quote size, however, is independent of the position of quote size in the book. This is why we put forward a new measure: *weighted depth*. Weighted depth is the weighted sum of the quantity available for trade. The weights are inversely related to the position of the quantity in the book. The quantity available at best price, i.e. best size, has weight equal to one. Any other quantity in the book has smaller weight and the weights are decreasing with the distance between best price and the price corresponding to the given quantity. Finally, *quote size per market participants* is calculated by averaging the quantity available for trade, which measures the average quantity exposed by each market participant.

3.1.3 Breadth

We employ only one measure of breadth: Steepness[16]. *Steepness* is the absolute difference between the best and the worst quote, scaled on the mid-point between the two. As we argued above, breath is the dimension of our classification whose relationship with the concept of liquidity is more controversial. However breadth provides interesting insights when combined with other dimension of liquidity.

3.1.4 Multidimensional measures

In order to overcome the ambiguity of steepness as a measure of market liquidity we developed new measures of liquidity. They are multidimensional measures because combining different dimensions of our taxonomy. We elaborate these new indexes as we expect their relationship with market liquidity being more clear-cut.

Slope is the ratio between the absolute difference between the best and the worst quote and the difference between quote size and best size. Geometrically, when we represent quoted prices on the vertical axis and the corresponding cumulative quantities on the horizontale axis, slope is the gradient of the linear interpolation between two points whose coordinates are best price and best size, on one hand, and worst price and total size, on the other hand. As long as the scatter diagram of quoted prices and corresponding cumulative quantities is concentrated around this interpolating line, slope measures the increase in marginal quoted price a dealer has to bear for trading € 100 mln,

[15] Average quote size matches quoted depth in Brandt and Kavajecz (2004).
[16] Steepness matches with steepness in Dunne et al. (2006).

additional to the best size[17]. As a consequence, the relationship between slope and market liquidity should be transparent: The higher the slope, the lower the liquidity. *DS* is a measure very similar to slope. The differential impact of trade on marginal quoted price, however, is not computed on the basis of a linear interpolation between two points. DS is the coefficient of the regression of quoted prices on the corresponding cumulative quantities. Obviously, the connection between DS and market liquidity is the same as the one between slope and liquidity: The smaller DS, the more liquid the market.

While slope and DS combine depth and breadth, *DSS* and *market quality index* combine tightness and depth. DSS is the estimate of another regression coefficient. In this case we regress the deep spread on the corresponding cumulative quantity. For each quantity in the order book deep spread gives the corresponding bid-ask spread. In other words, when the quantity on the bid side of the order book has a corresponding quantity on ask side, we compute the spread insisting on that quantity.[18] DSS measures the increase in marginal spread that a dealer has to bear for an additional purchase and sale of the security. Conceptually, it is very close to DS and slope and it has the same relationship with market liquidity. Market quality index is not a new measure as those presented above[19]. It is computed by taking the ratio between average quote size and spread scaled on the mid price. It measures the average quote quantity per percentage point of spread. The higher is the index, the higher the liquidity. For reasons that will be clear later, we also employed a modified specification of the measure as well. In *market quality index 2* quote size substitutes for average quote size at the numerator of the index.

Finally, following Cheung et al. (2005) we adapt to the bond market the Irvine et al. (2000) percentage *cost of the round trip* (henceforth CRT). This is the weighted average price at which a double order of sell and buy of size *L* could be immediately executed at time *t*. The best spread is a particular case of the *CRT* when the best size is larger than *L*. CRT combines tightness and depth as well. Obviously, a smaller CRT indicates a more liquid market. In order to choose *L*, we worked out the distribution of trade sizes for all the securities in the sample. It turns out that the most frequently traded quantities for MTS Italy are 2.5, 5 and 10 million of euros[20]. In what follows we will focus on the *CRT* for *L = 10* and we will call it *CRT10*.

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[17] Slope is analogous to the price impact coefficient, i.e. the Kyle lambda, in Fleming (2003). However, slope is an order book measure, on the contrary price impact coefficient is calculated on trade data.
[18] The deep spread is elaborated by the Treasury and it is available to us.
[19] Market quality index matches with market quality index in Boll and Whaley (1998) and in Berber et al. (2006).
[20] Following Cheung et al. (2005) we evaluate the *CRT* also for *L = 25*.

3.1.5 Market conditions

We use a couple of indicators to measure market conditions. *Market participants* measures the number of active market makers in each snapshot. It will be considered as an indicator of the degree of competition among the primary dealers. *Absolute price change* is our measure of market's volatility. It is the absolute difference between the average mid prices of two following snapshots. Even if the two measures are frequently used to proxy liquidity, we consider them as indicators of market conditions.

3.2 Trading measures

The measures introduced so far exploit order book data. Now we turn to measures that rely on trading data. A first common measure is *trading volume*, measured as the traded quantity multiplied by the contract price and then aggregated over a 5-minute interval. Other popular measures are the *trading frequency* and the *turnover ratio* that are respectively the number of contracts in a given time interval and the ratio between trading volume and the outstanding, that is the issued quantity of a given security. *Trade size* is simply the average size of trades in the 5-minute interval[21]. A widespread liquidity measure, which arises from an econometric estimation, is the *price impact coefficient*. In effect, a liquid market is a market where participants can rapidly execute large-volume transactions with a small impact on prices, and this measure just estimates the price impact of trades. Firstly introduced by Kyle (1985), both Fleming (2003) and D'Souza, Gaa and Yang (2003) underline the importance of its estimation. We estimate the following model:

$$\frac{P_t - P_{t-1}}{P_{t-1}} = \alpha + \beta * NT_t + \varepsilon_t \qquad (1)$$

Where *NT* is a measure of market activity and more precisely it is either *net trading quantity* or *net trading count*[22]. Even though it necessitates the use of detailed high-frequency data, equation (1) needs to be estimated over a long sample period. We estimated the model both over the whole sample and weekly. We use the weekly regression coefficients as measures of the price impact, and we call them *NTQ* and *NTC*, respectively[23].

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[21] Trading volume, trading frequency, turnover ratio, trade size match with the measures employed in D'Souza and Gaa (2004) and Fleming (2003), among others.

[22] Net trading quantity and net trading count match with the variables employed in D'Souza and Gaa (2003).

[23] In the following analysis we will also provide an estimation of several specifications of the model, as in Fleming (2003), for the whole sample.

4. The Italian Government Securities Markets

The Italian Government finances its public deficit by issuing debt securities, on December 2006 they accounted for 80% of the public debt. The Italian market for GS consists in two sectors: The primary market[24] and the secondary market. In the primary market bonds and notes are mainly placed through auction mechanisms. The Italian Treasury avails itself of a Primary Dealership system. Among Primary Dealers it chooses a group of so called Specialists, which status entails themselves of privileges and obligations: For instance, Specialists have the faculty to participate to reserved auction reopening, but they have to provide certain levels of liquidity both to the cash and to the Repo markets to preserve their status. In the secondary markets GS are traded in two ways, namely in organized exchange markets and over-the-counter. In the latter the main players are investment banks and most of them participate also to the primary market. In the former we can distinguish a retail market (i.e. the MOT) and a wholesale market. The majority of trading occurs on wholesale markets. In particular, among the wholesale markets, MTS (*Mercato Telematico dei titoli di Stato*) is the leading market in Europe for the trading of fixed income securities with its over 1200 participants throughout Europe and average transaction volumes of up to 85 billion euros a day (single-counted)[25]. Italian bonds, however, are quoted on other trading electronic platforms as well. In Europe electronic trade accounts for 75% of daily trade volume for Government bonds[26]. Since the analysis of the primary market is beyond the scope of this paper, this section will focus on the secondary market and in particular on the MTS market.

4.1 MTS model: An overview

"In defining the MTS model, a choice was made to create a two-tiered market - a central "super wholesale" market for European government bond benchmarks, and a combination of domestic markets aimed at creating liquidity for national issuers while exploiting a European network of operators and the economies of scale that a single technological platform offers"
(http://www.mtsgroup.org/newcontent/search/)

MTS was the first electronic market for GS and it was introduced in 1988 by the Italian Treasury as a platform for co-ordinating the activity of its primary dealers group within Italy. The original model required that, in exchange for committing liquidity, banks would be recognised as primary dealers, and they would gain the right to participate in auctions and receive a steady supply of new issues; however, this model was limited to the single issuer within the lira currency zone.

[24] For a deeper analysis of the primary market see Bagella et al. (2006).
[25] Source: MTSGroup web site.
[26] See Pierron (2004).

The following development of MTS, from the privatisation in 1997 to the establishment of EuroMTS in 1999[27], tracks the development of the European bond markets. Indeed, the introduction of the euro and the progress of electronic trading and settlement motivated MTS to develop a strategy to exploit the new-found scalability of its model across both geography and bond type. Moreover, with the beginning of the single currency zone, the dealer community supported the emergence of specific standards related to issuance sizes and transparency of the issuance policy. Eventually, the MTS platform became the natural catalyst for setting common standards of bond issuance, quotation requirements and transparency of the issuance policy. The first stage was the foundation of EuroMTS, the pan-European benchmark platform, to promote such standards, and the birth of the so called *Liquidity Pact*. According to the Pact, dealers and issuers undertake commitments to each other, and the MTS platform is used by both sides of the market to monitor and bring transparency to it.

The key to the success of this trading platform is to be found not only in its technical capabilities, but also in MTS's ability to bring together issuers and dealers and to induce them to commit to a few simple rules. The aim was to foster secondary market liquidity. In addition, in some countries the quoting and trading performances on MTS are taken into account by Government debt management offices to admit dealers to the primary market. As many other multilateral agreements, the *Liquidity Pact* comes with benefits but also with costs since it may favour free riding: Any participant can profit from the liquidity provided by the other participants and make other dealers to lose money[28].

The last stage of the MTS transformation consisted in the merger of EuroMTS with MTS S.p.a. into MTS Global Market in 2001. Moreover, since the end of the nineties the MTS system expanded to other country markets and to high quality non government bond[29]. The MTS model uses a common trading platform; however, regulatory responsibilities are within the competence of domestic authorities. In effect, rules governing electronic platforms share some common characteristics, but there are some differences across countries. For instance markets makers must have net assets of at least €100 million to join MTS Belgium and just €39 million to join MTS Italy. Shares in EuroMTS are held by MTS S.p.a., whose shareholders are Borsa Italiana S.p.a. and the

[27] Scalia and Vacca (1999) provide a description of the developments of the Italian Treasury securities secondary market occurred in the last two decades.

[28] For instance, in August 2004 Citigroup in few seconds flooded MTS with sales and then it repurchases a large amount of bond at a lower price, earning about 15 million euros at the expense of the other market makers, see Munter and van Duyn (2004).

[29]On March 2007 the markets of the MTS platform are the following: EuroMTS , MTS S.p.a. (MTS Italy), EuroCredit MTS, NewEuroMTS, EuroBenchmark Treasury Bills Market, EuroMTS Linkers Market, MTS Cedulas Market, MTS Quasi-Government Market, EuroGlobalMTS, MTS Amsterdam, MTS Austrian Market, MTS Belgium, MTS Denmark, MTS Deutschland, MTS España, MTS Finland, MTS France, MTS Greek Market, MTS Ireland, MTS Israel, MTS Poland, MTS Portugal, MTS Slovenia, BondVision, EuroMTS Indices.

major financial institutions that have a strong presence in the European secondary government bond markets[30].

4.2 MTS microstructure

Let now consider the structure and functioning of MTS. MTS is a wholesale inter-dealer market, this means that individuals cannot access to it. Although the requirements for participants depend on the market in which they operate, we can broadly distinguish two categories of participants, namely market makers and market takers. The former have to quote continuously two-way firm and immediately executable proposals for a selected subset of securities. The prices usually have to be posted for at least five hours per day and for a certain minimum quantity, and they are subject to maximum spread obligations depending on bonds maturity and liquidity[31]. Each market maker can voluntarily quote other securities as well, facing in this case no constraint on price proposals. No market making obligation applies to market takers that can buy or sell at the given prices. MTS markets are an example of quote-driven electronic order book. This implies that market makers' quotations are aggregated in a book according to price and side of the market. Since orders of round lots[32] are executed according price priority and time priority (i.e. first in first out) and the quoted proposals are firm and immediately executable, we can say that MTS works as a limit order book. To facilitate the handling of large transactions, minimum lot sizes[33] are high and trading rules grant traders a high degree of anonymity[34]. In effect, price proposals are anonymous and the identity of the counterparty of a trade is revealed only after the trade is executed for clearing and settlement purposes. In particular, if a central counterparty (CCP) is used, counterparties will not know identities; if the trade is settled bilaterally, only the counterparties will know identities. Moreover, market makers are not required to show the maximum quantity they are willing to trade: A participant may limit the display of his proposals to a partial amount (drip quantity) between the minimum trading lot and the total amount of the proposal (block quantity). Both cash and repo transactions are admitted[35]. Even if anonymity in transactions is guaranteed, the MTS system is highly transparent since quotes and transactions go directly to data vendors. As a result, they are

[30] Till recently, one of the main shareholders of MTS S.p.a. had been Euronext, the company which controls the Paris stock exchange and other major stock exchanges in Europe. In the occasion of the merge between Euronext and New York Stock Exchange, the shares of MTS S.p.a. owned by Euronext were bought back by Borsa Italiana S.p.a..

[31] See Table 4.1.

[32] Odd lots are admitted but they are subject to market makers' acceptance.

[33] Proposals must be formulated for a minimum quantity equal to € 10, € 5 or € 2.5 million depending on the instrument (bucket of maturity, liquid/ benchmark security).

[34] Actually, this was not the case when MTS was founded. Indeed, in July 1997, 10 years after its inception, MTS switched to a new operation regime in which the names of market-makers who post bid and ask quotes for each security are not revealed. Scalia and Vacca (1999) analyze this change in the degree of transparency.

[35] For additional details see "MTS Regulations - Governing the Wholesale Italian and Foreign Government Bond Market" available at http://www.mtsspa.it/content/about/download/mtsmarketrules.pdf.

immediately available, at a cost, to any market participants. Moreover, data [36] provide the information about the first five levels of the order book.

Both pre- and post-trade[37] information is available outside the electronic platform space in real-time. Dealers on the MTS platform have access to real-time executable quotes and to a fully transparent order book. Professional investors have an indirect access to the same information through data vendors. In particular, the MTS group aggregate information through the so called MTS Data. MTS's data products are grouped into two areas, namely MTS Live Market Data and MTS Value- Added Data. MTS Live Market Data[38] includes *real time* bond market data providing best bid and offer quotes, market depth, as well as the last traded price, all complete with related volumes. It is important to underline that these prices are actual traded prices or prices that are live and executable on the MTS platform. Data are available to data vendors[39] also at snapshot[40], delayed and end-of -day frequencies. MTS Value-Added Data Products are made up of MTS Daily Data, MTS Historical Data, EuroMTS Indices and MTS Today, which is a daily analytics report. In particular, MTS Daily Data includes the reference prices[41] and corresponding yields calculated for all European government, Treasury bills and non-government bonds traded on MTS Markets at 11:00 CET as an "Open" fixing and at 16:00 CET as a "Close" fixing. These prices are published immediately after each fixing. With respect to data available to anybody at no cost, the daily price statistics of MTS Markets for cash and repo segments can be accessed and downloaded by selecting the corresponding MTS market on the MTS Group's website. These lists are updated daily at the close of the market and display the date of trading, the ISIN code, the type of bond, the description of each security and the minimum and maximum price of trades executed along with the average daily weighted price for each security.

As already mentioned, MTS markets are active in several European countries, an exception is the London-based EuroMTS, designed for trading in European benchmark issues between the largest and most active dealers. An interesting feature of this system is that benchmark Government bonds tend to be traded both on EuroMTS and on domestic (MTS) systems. In the period 2004-2006 only 5% of the Italian bonds and notes exchanged on electronic systems have been traded on

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[36] Both cash and repo data are displayed.

[37] For an assessment of pre- and post-trade information, from the perspective of the transparency provisions envisioned in 2004/39/EC Directive disciplining the functioning of markets for financial instruments in Europe (MiFID), see Paesani and Piga (2007).

[38] MTS Market Data is managed by EuroMTS on behalf of the group of MTS Companies.

[39] The complete list of data vendors includes: Bloomberg LP, Interactive Data Comstock, E-class/Class Editori, Ecowin, Fininfo, FTID, Il Sole 24 Ore, Infotec, Kestrel Inc., Moneyline Telerate, Reuters, Russell Mellon, SIA Cedborsa, Telekurs Financial, Thomson Financial, Traderforce, Valuelink Information.

[40] For instance Traderforce's clients are allowed to download all the data available at a certain point in time as if they "take a picture" of the market in that moment.

[41] The algorithm to generate a final Reference Price for each product utilizes both traded prices and quoted best prices, and weights the two.

EuroMTS and about 95% on MTS Italy[42]. CGFS (2001) analyses the daily trading volumes and bid-ask spreads of benchmark Italian government bonds (BTPs) quoted on MTS Italy and shows that no substantial change in liquidity conditions occurred in this market in the first five months of activity of the new pan-European network, i.e. from April to August 1999. This suggests that the latter has mainly captured transactions that were previously carried out over the counter. Cheung et al. (2005) notice that in general large numbers of market makers are active on both trading platforms, suggesting that there are not any competitive advantages in terms of quoting rights. Furthermore, they show that, although domestic MTS markets usually offer better spreads, the difference with the EuroMTS is small.

One important feature of MTS Italy is in the different set of market makers' obligations. In effect, the Italian Treasury, as mentioned above, defines a set of obligations and privileges for Specialists. Since the majority of market makers are also Specialists, this regulation affects the markets. In particular, the Treasury requirements are usually stricter with respect to the MTS ones, and, as a consequence, most of the market participants are committed to the Treasury's obligations. Table 4.1 summarizes the differences between the set of rules imposed by MTS Italy and those imposed by the Ministry of Economy and Finance (MEF), to which are subject the securities in our sample[43]. The two regulations pursue liquidity in quite different ways. MEF rules apply to all the securities available on the market and, as a consequence, also to all the off-the-run issues. On the other end, the Management Company (i.e. MTS) periodically assigns to Primary Dealers buckets of securities that are "suitably differentiated in terms of liquidity, maturity date and other financial characteristics, for a minimum number laid down in the Rules, taking account of the need to ensure real competition between the Primary Dealers" (Art. 17, MTS Regulations, Governing the wholesale Italian and foreign government bond market, 2005). The main distinction is between the "liquid" bucket and the "not liquid". For the period under examination, i.e. 2004-2006, a security is said to belong to the "liquid" bucket if it is listed on EuroMTS. It turns out that all the bonds in our sample would be assigned to the "liquid" bucket, which is also the one that is subject to the most severe commitments[44]. In effect, MTS defines precisely for each bucket bounds of maximum spread and minimum quoted quantity. The approach of the Italian Treasury is totally different. The Treasury monitors Specialists awarding points which are proportional to how the Specialist makes the market with respect to the other participants. For instance, points are assigned according to a

[42] Source: our elaboration on Monte Titoli Spa data.
[43] The securities included in our samples are listed in section 5.
[44] This is not the case for CTZs for which there is no bucket distinction.

measure of spread that is standardized with respect to the market of all the traded securities[45]. The Bank of Italy participates as well in the Treasury monitoring activity through the computation of the Efficiency Index. This index keeps into account the number of quoted and traded securities, and quoted bid-ask spread and quantities weighted for the exposition time on the order book. The obtained scores allow MEF to rank Specialists: ranking is one of the criteria used by Italian Treasury in order to select Specialists for highly remunerative services such as private placements[46].

Table 4.1 MTS and Treasury rules applying to the securities comprised in our sample

	Compliance time		**Bid-Ask Spread**		**Volume**		**Other**	
	MTS	MEF	MTS	MEF	MTS	MEF	MTS	MEF
securities	all assigned bond	all	"liquid" bucket max spread	all	"liquid" bucket min quote size (mln)	all	–	all
BTP30	Two-way proposals displayed for at least 5 hours per day	Points proport. to the number of GS quoted for at least 6 hours	0.2	Points proport. to a standardized spread#	2.5	Points proport. to (%Specialist 's traded volume - average % of the non-Specialist)	–	Bank of Italy "Efficiency Index"* and distributiona l capacity based on HRF**
BTP10			0.07		5			
BTP 5			0.05		5			
BTP 3			0.04		5			
CTZ			0.04^{+}		2.5			
BTP 10 ind			–		2.5			

Note: The rules apply to the time span and the securities in the present research. Sources of the information are respectively www.mtsspa.it and "MTS Regulations - Governing the Wholesale Italian and Foreign Government Bond Market" for MTS and the Annex to the Public Director Decree N.140483 of December the 29th 2005 for the Italian Treasury. # the formula is displayed in footnote 45. + the same bound applies to "not liquid" bucket. The "liquid" bucket includes on-the-run and first off-the-run securities. * the index keeps into account the number of quoted and traded securities, and quoted bid-ask spread and quantities weighted for the exposition time. **since 2006, the parameter is evaluated quarterly on the basis of *Harmonized Reporting Format*.

5. Methodology and Data Description

[45] The index is calculated as the simple average of the standardized bid – ask spreads for all the bonds quoted daily for at least 6 hours. For a generic primary dealer (PD) *X*, the standardized spread for bond *i* quoted for at least 6 hours is equal to:

$$z_i^X = \frac{s_i^X - \overline{s_i}}{\sigma_{s_i}}$$

Where s_i^X is the daily average spread of the bond *i*, quoted for more than 6 hours by the PD *X*, calculated by weighting each bid-ask spread by the exposition time. $\overline{s_i}$ and σ_{s_i} are, respectively, the average and standard deviation of the spreads of bond i, calculated as indicated before, for all the Primary Dealers.

[46] All the information related to Specialists (i.e. list, ranking and evaluation criteria) are available online at http://www.dt.tesoro.it/Aree-Docum/Debito-Pub/Titoli-di-/Aste-Titol/

5.1 Methodology

Each of the previous liquidity measures describes a particular aspect of the market. In the case of MTS market, the quality of the order book is particularly relevant, as the quotes on the book are firm and immediately executable. Therefore, the features of the order book and their evolution in time define the amount of liquidity provided by the market makers. In this respect, trade measures can be used in order to verify if the liquidity provided by the order book is consistent with the trade needs revealed by the market.

Despite the relevance of MTS among GS markets and the huge amount of information contained in the available data, to our knowledge no previous research has given systematic and thorough evidence on MTS order book. Therefore, our preliminary and main aim was the exploitation of the data set and the presentation of a consistent set of indicators and measures, which could give comprehensive description of the most important features of order book and trading data.

In particular, we followed the following steps:

- computation of old and new measures and indicators both on high frequency data and on a weekly basis;
- selection of the measures and indicators which give the most useful and efficient description of market liquidity. This evaluation was based, first, on univariate analysis and, second, on the correlations between measures and indicators, in order to assess their reciprocal consistency and their reaction with respect to indicators of market conditions;
- computation of measures and indicators on sub-samples of data in order to assess the robustness of the empirical results. Namely, the dataset was split between on-the-run and off-the-run securities, between hours of trade concentration and rest of the day;
- liquidity comparison across securities of different maturity and analysis of the commonality in market liquidity.

The selection of our preferred measures will follow the criteria specified in Fleming (2003): A liquidity measure should directly quantify the transaction costs, it should behave consistently with market participants' view about liquidity, it should be easy to calculate and be available on a real-time basis.

5.2 Data

Our dataset covers transactions and proposals of the Italian medium and long term GS being traded on the MTS platforms from January 2004 to December 2006. For each day in the sample we have the on-the-run and the corresponding off-the-run security for each segment. The series of each security ends six months after it becomes the second off-the-run. Table 5.1 reports the exact time span for each security in the dataset. We mainly focus on medium and long term fixed coupon bonds (BTPs), which on December 2006 accounted for 59.93% of the outstanding securities. We also consider two year zero coupon bonds, CTZs, and the ten year index linked BTPs.

Data are provided by the Italian Treasury that collects them directly from the MTS Italy market. *Ad hoc* software allows downloading the data at the desired frequency. This data source is somehow unique since it shows all the quotes and the relative quantities that are active on the market. The implication is that we are allowed to see the complete book, whereas traders can only access a part of this information. Indeed, while market participants can see just the five best bid and ask quotes and the drip quantities insisting on them, our dataset includes *all* the non-repeated quotes and for each quote we know the whole (block) quantity (unfortunately drip quantities are not available to us at present). This will permit us to provide particularly accurate measures of the depth of the market. As we will show in the next sections, when we have more than five bid (ask) prices in the order book, the prices beyond the fifth are usually so low (high) to be irrelevant[47]. The minimum increment in quoted prices, i.e. the tick size, is one hundredth of the price for all the securities in the sample but CTZs, whose tick size is one thousandth of the price. Each row of the database is a "snapshot" of the information related to a certain security at a precise point in time. The dataset contains all the snapshots between 8:30am and 5.30pm at a five-minute frequency[48]. All the contracts are also available and they include the price, the sign of the trade and the trade time. Information about the number of market participants and the number of times a quote (either price or quantity) has been updated in the previous five minutes is also available.

The raw dataset contains some errors due to missing records and outliers. We filtered data prior to performing our analysis; the filtering methodology is described in Appendix A. Transactions and quotes are available for both on-the-run and first off-the-run securities, where for on-the-run we mean the most recently auctioned security. We end up with 8,371,861 proposals and 172,623 contracts.

[47] This is not true in the case of CTZs, as we specify below.

[48] We ran a preliminary analysis on samples selected at both 30 seconds and 10 minutes frequency. The 30 seconds frequency data did not show a significant amount of additional information.

Table 5.1 - Data

Security	Isin code	on/off the run	From	Coupon rate	Maturity	Starting data	End sample	Numb. quotes	Numb. contracts
BTP30	325682	off	17-Sep-03	5.75%	1-Feb-33	1-Jan-05	30-Nov-05	1,432,618	9,210
	353515	on off	17-Sep-03 12-Oct-05	5%	1-Aug-34	1-Jan-05	31-Dec-06		
	393465	on	12-Oct-05	4%	1-Feb-37	12-Oct-05	31-Dec-06		
BTP10	347233	off	29-Jan-04	4.25%	1-Aug-13	1-Jan-04	13-Nov-06	1,311,264	59,491
	361838	on off	29-Jan-04 30-Aug-04	4.25%	1-Aug-14	27-Jan-04	13-Nov-06		
	371991	on off	30-Aug-04 28-Apr-05	4.25%	1-Feb-15	27-Aug-04	13-Nov-06		
	384453	on off	28-Apr-05 27-Feb-06	3.75%	1-Aug-15	27-Apr-05	13-Nov-06		
	401958	on	27-Feb-06	3.75%	1-Aug-16	23-Feb-06	13-Nov-06		
BTP 5	353209	on off	15-Sep-03 13-Apr-04	3.50%	15-Sep-08	1-Jan-05	28-Feb-05	830,961	23,577
	365207	on off	13-Apr-04 13-Jan-05	3%	15-Apr-09	13-Apr-05	31-Jul-05		
	379959	on off	13-Jan-05 15-Jun-05	3%	15-Jan-10	11-Jan-05	13-Mar-06		
	387292	on off	15-Jun-05 13-Mar-06	2.75%	15-Jun-10	13-Jun-05	17-Nov-06		
	402629	on off	13-Mar-06 14-Sep-06	3.50%	15-Mar-11	13-Mar-06	17-Nov-06		
	411281	on	14-Sep-06	3.75%	15-Sep-11	12-Sep-06	17-Nov-06		
BTP 3	361115	on off	14-Jan-04 28-May-04	2.75%	15-Jan-07	14-Jan-05	28-Feb-05	783,354	32,115
	367423	on off	28-May-04 28-Jan-05	3%	1-Jun-07	28-May-05	31-Jul-05		
	380485	on off	28-Jan-05 28-Jun-05	2.75%	1-Feb-08	28-Jan-05	28-Feb-06		
	387770	on off	28-Jun-05 30-Jan-06	2.50%	15-Jun-08	28-Jun-05	31-Jul-06		
	400812	on off	30-Jan-06 28-Jun-06	3%	1-Feb-09	30-Jan-06	31-Dec-06		
	408524	on	28-Jun-06	4%	15-Jun-09	28-Jun-06	31-Dec-06		
CTZ 24 m	364676	on off	29-Mar-04 27-Jul-04		28-Apr-06	24-Mar-04	28-Apr-06	2,933,702	44,387
	369706	on off	27-Jul-04 24-Mar-05		31-Jul-06	23-Jul-04	25-Jul-06		
	383119	on off	24-Mar-05 27-Sep-05		30-Apr-07	22-Apr-05	1-Dec-06		
	392699	on off	27-Sep-05 24-Apr-06		28-Sep-07	23-Sep-05	29-Dec-06		
	405105	on	24-Apr-06		30-May-08	21-Apr-06	29-Dec-06		
BTP 10 ind	362590	on off	18-Feb-04 23-Jun-06		15-Sep-14	3-Jan-05	29-Dec-06	1,079,962	3,843
	408521	on	23-Jun-06		15-Sep-17	22-Jun-06	29-Dec-06		
total								8,371,861	172,623

6. Empirical Results

In the previous sections we presented a number of conventional and new measures in order to assess the market liquidity. In this section we display the results of the empirical analysis. We start with univariate statistics focusing on the 10 year BTPs[49]. The data are at 5-minute frequency in the case of the order book measures, and at daily frequency in the case of trade measures. Furthermore, we compute the price impact coefficient both on the whole sample and at weekly frequency. We then present the correlation coefficients, both at 5-minute frequency and at weekly frequency[50], among those measures in order to show their mutual relationships, reciprocal consistency, and reaction to market conditions. Finally, we compare at weekly frequency the liquidity measures across all the securities in the sample. This analysis also allows us to evaluate commonality in liquidity. When possible, we compare the values of the liquidity measures we found on MTS with the values of the same measures on other platforms for analogous government securities. Our yardsticks were one of the major Interdealer Broker electronic platforms in the U.S., BrokerTec[51], and the Canadian Interdealer Brokered market for Government bonds[52]. On those markets we considered the on-the-run 10 year maturity bond. The typical 10 year government bond in U.S., Canada and Italy have different outstanding. The total issued amounts are US$ 22-28 mln, CA$ 10 mln, € 20-25 mln, respectively, in the period 2004-2007. Taking this major difference into account, we claim that the comparison among the same liquidity measures is still informative.

6.1 Summary statistics

Table 6.1 refers to the order book measures at a 5-minute frequency. Table 6.2 and 6.3 refer to trade measures at daily frequency, except for trade size, which is calculated on all the contracts in the sample. The tables, at the end of the present section, are split in two panels, A and B: the former is computed on on-the-run securities, the latter on off-the-run securities[53].

6.1.1. Tightness

The average value of the best spread amounts to 0.025 per cent of par. The dispersion around the average is small. The average value of both spread and weighted spread are, by definition, larger than the best spread. However their dispersion around the average value is even

[49] We mention in footnotes when the evidence on the other securities in the sample is not consistent with the one on 10 year BTPs.
[50] Appendix C collects univariate statistics and correlations computed on the other securities included in the sample.
[51] Data were drawn from Fleming and Mizrach (2007).
[52] See D'Sousa, Gaa, Yang (2003).
[53] We comment here only panel A. The comparison between panels A and B is delayed to section 7.

narrower than best spread's one[54]. The average best spread on MTS turns out to be larger than the best spread on the on-the-run 10-year maturity U.S. Treasury note[55], which amounts to 0.015 per cent of par. However, it is greatly smaller than the best spread on the on-the-run 10-year Government of Canada bond, which amounts to 0.076 per cent of par[56].

Figure 6.1 is worked out averaging each 5-minute interval over the whole sample. In the top left panel *best spread* shows a sort of U-shaped pattern. The highest value is achieved at the beginning of the day and it is around 4 ticks, then after 9.00 it falls at 2 ticks and it gradually rises again after 15.00. This is consistent with the empirical findings of Huang et al. (2002) for the USA Treasury Interdealer Broker market (IDB). The peak around 14.30 coincides with the opening of US financial markets. While the peak is common to all the measures of spread, the U shape is not so clear in the case of spread, and weighted spread is only slightly hump-shaped.

6.1.2. Depth

The quantity available for trade in the whole order book amounts, on average, to € 157 mln. However, only 24 per cent of it, € 37 mln, is available at the best quotes. Another 48 per cent of it is available at the second best quote. The average best size on MTS turns out to be smaller than the best size on the on-the-run 10-year maturity U.S. Treasury note[57], which amounts to $ 48 mln. However, it is much larger than the best size on the on-the-run 10-year Government of Canada bond, which amounts to $ 2.4 mln[58].

The dispersion of quote size around its average value is large, particularly in the case of best size[59]. Data show that each market maker is available to trade € 8 mln on average and the dispersion around that average value is very small[60]. This means that the high variability of quote size mainly depends on the number of dealers who participate in the market[61].

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[54] Best spread is even tighter, 0.023, and less dispersed in the hours of trade concentration, i.e. between 9:00 a.m. and 2:00 p.m. However, spread and weighted spreads are marginally larger in the hours of trade concentration. Data on the other securities in the sample confirm the same evidence, particularly in the case of spread. We will come back on the rationale of the wider spread in hours of trade concentration.
[55] See Fleming and Mizrach (2007).
[56] See D'Sousa, Gaa, Yang (2003).
[57] See Fleming and Mizrach (2007).
[58] See D'Sousa, Gaa, Yang (2003).
[59] In hours of trade concentration quote size is even larger than on average. However, the increase in size during the hours of trade concentration is not uniformly distributed on all the order book. The comparison of hours of trade concentration and the rest of the day shows that total quote size jumps from € 113 mln to € 190 mln. On the contrary, best size increases only from € 31 mln to € 42 mln. Furthermore, while in the hours of trade concentration the dispersion of total quote size significantly falls, the coefficient of variation of best size keeps on being larger that 0.5. Other securities in the sample generally confirm previous evidence on quote size. However, in the case of BTP3 and BTP5, the increase of quote size in the hours of trade concentration is smaller.
[60] Even during the hours of trade concentration the quote size per participant is not larger than it is on average. On the contrary is slightly smaller.
[61] Most of the variability in the number of participants to market depends on the fall in market participation in morning and afternoon hours. In the hours of trade concentration, on average the market is made by 23 dealers. On the contrary, in the rest of the day, the number of market participants falls to 14. See Figure 6.1 for the graph of daily evolution of the

In the top right panel of Figure 6.1 depth measures show a hump-shaped pattern with lower values at the beginning and at the end of the day. The *weighted depth*, that takes into account the position of the quoted sizes in the book, follows the pattern of the other depth measures but at the same time underlining the changes in liquidity during the day. The fall in liquidity at 2:30 p.m. is evident in this case as well. Indeed, it turns out that at that time some market participants leave the market. Conversely, the participants that do not exit reduce the quoted size and widen the spreads. The reduction of the quote size per market participant is consistent with Kavajecz (1999), who finds that traders reduce depth around information events to reduce their exposure to adverse selection costs. This phenomenon disappears in the following 5-10 minutes.

6.1.3. Breadth

The average distance between best and worst quote, the steepness, amounts to 3 per cent of the mid price. The median value of steepness, however, is smaller, 2 per cent. Interestingly the steepness, which is sometimes regarded as a measure of liquidity[62], seems to behave not consistently with the other measures of liquidity. Indeed, the bottom left panel of Figure 6.1 shows that during the hours of trade concentration, when the spread variables and the size variables indicate higher liquidity, we find higher values of the steepness and therefore apparently lower liquidity, according to one of the interpretations of this measure. We will elaborate on steepness and its relationship with liquidity measures later on. For the time being, suffice to say that, as long as we correct the *steepness* to keep into account the underlying quantities, as in the *slope*, we obtain a measure whose conceptual relationship with liquidity is clearer. The slope computes how far from best price a dealer has to depart. Therefore, the smaller the slope, the more liquid the market is. Accordingly, the figure shows that the slope falls in the hours of trade concentration. *DS* and *DSS* exhibit a pattern that is very close to the slope's one.

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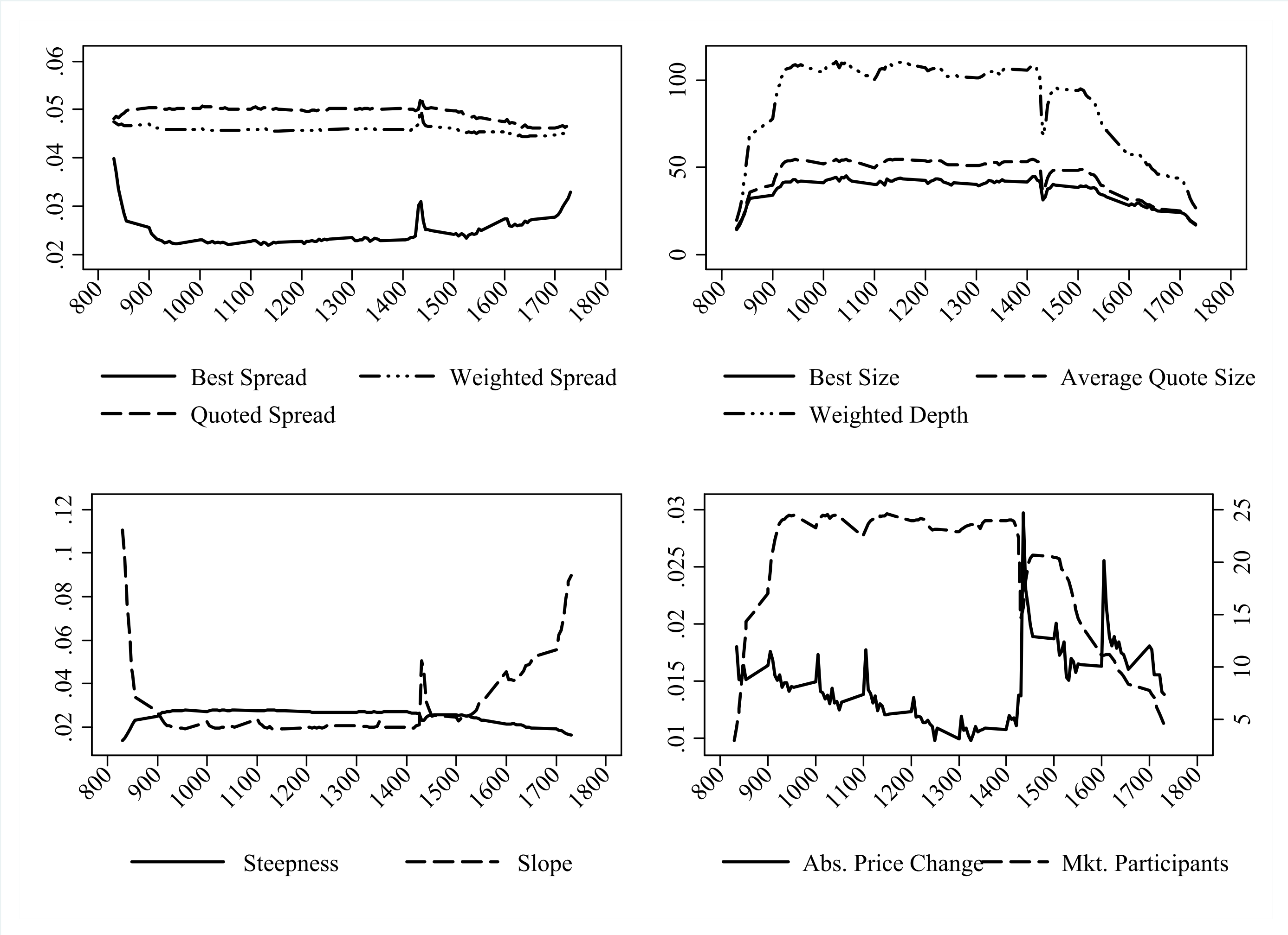
number of participants. Furthermore, the dispersion in the number of market participants around those average values is small in the hours of trade concentration and large in the rest of the day.

[62] See for instance Dunne et al. (2006).

Figure 6.1 Daily pattern



Note: Five minute data are averaged over the whole sample of the on-the-run 10 year BTPs. The spreads are measured in ticks. The depth measures are expressed in millions of euros. In the bottom left panel the left scale refers to the absolute price change measured in ticks and the right scale to the number of market participants.

Table 6.1 – Summary statistics of order book measures

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
best spread	0.025	0.010	0.020	0.020	0.030	0	0.280
spread	0.049	0.008	0.045	0.050	0.055	0.010	0.280
weighted spread	0.046	0.007	0.043	0.045	0.048	0.010	0.283
best size	37.24	22.97	20	32.5	50	2.5	170
second size	75.77	35.10	50	77.5	102.5	3.75	215
worst size	47.02	31.18	22.5	45	70	0	195
quote size	157.09	62.66	112.5	175	205	5	310
average quote size	45.34	16.94	33.8	48	57	3.75	137.5
weighted depth	88.74	35.51	64.38	93.96	113.75	5	212.5
qte size per partic.	8.18	1.09	7.63	8.07	8.61	1	37.5
steepness	0.03	0.01	0.02	0.02	0.03	0.01	0.06
slope	0.03	0.03	0.02	0.02	0.03	0.01	0.5
DS	3.37	3.25	1.71	2.22	3.44	0.67	42.46
DSS	0.0004	0.0006	0.0002	0.0003	0.0004	0.0001	0.023
mkt quality index	9.43	3.79	6.81	9.52	11.98	0.19	33.51
CRT 10	0.02	0.01	0.02	0.02	0.03	0.00	0.29
abs price change	0.015	0.016	0.005	0.01	0.02	0	0.318
mkt participants	19.31	7.63	14	22	25	1	32
Panel B: off-the-run							
best spread	0.025	0.010	0.020	0.020	0.030	0	0.280
spread	0.049	0.008	0.045	0.050	0.050	0.000	0.290
weighted spread	0.045	0.007	0.042	0.044	0.047	0.000	0.290
best size	39.15	24.32	20	32.5	53	5.0	198
second size	81.16	36.55	55	85.0	107.5	5.00	245
worst size	41.44	28.65	17.5	38	60	0	203
quote size	158.56	62.85	115.0	180	205	5	325
average quote size	46.51	16.79	35.4	49	58	5.00	135.0
weighted depth	91.53	36.34	66.67	97.08	116.67	5	229.6
qte size per partic.	8.28	1.05	7.76	8.25	8.75	2	90.0
steepness	0.02	0.01	0.02	0.02	0.03	0.01	0.06
slope	0.03	0.03	0.02	0.02	0.03	0.01	0.4
DS	3.17	3.19	1.62	2.07	3.14	0.41	31.58
DSS	0.0004	0.0005	0.0002	0.0003	0.0004	0.0000	0.020
mkt quality index	9.92	3.74	7.47	10.15	12.39	0.18	33.18
CRT 10	0.02	0.01	0.02	0.02	0.03	0.00	0.28
abs price change	0.014	0.015	0.005	0.01	0.02	0	0.318
mkt participants	19.33	7.69	14	22	25	1	31

Note: The table report summary statistics for the 10 year BTPs' database at a 5-minute frequency. Panel A refers to on-the-run and Panel B to off-the-run issues. "p" is the p-th percentile of the distribution.

6.1.4. Trading measures

Do the order book features fit with the trading needs revealed by market? Table 6.2 shows that the average trade size amounts to € 6.5 mln and the corresponding coefficient of variation is equal to 0.37. Furthermore, Table 6.3 shows that, for most of the securities in the sample, the frequency of trades whose size is larger that €10 mln is smaller than 2 per cent. The comparison of trade size data with best size data shows that the quantity available on the book at the best price seems to be adequate to the revealed trade needs of the market. On average, at the best price, an amount of € 37.2 mln is available for trade, and best size is larger than € 20 mln in 75 per cent of cases. Even though more careful analysis of execution quality could be carried out, a tentative supposition could be put forward: Most of trading could occur at the best price. A further confirmation of the possible good execution quality comes from the Cost of the round trip for an amount of € 10 mln: CRT and best spread show very similar values of the descriptive statistics. This means that buying and selling a quantity larger than the size of most of the recorded trades has a cost that is equal to the best spread[63]. However, trade size could be affected by best size and the causality could be reversed: most of the trading concentrates around € 6.5 mln because larger amounts are discouraged to appear on MTS, given the limited best size available. For the time being we are not able to give a final answer to the issue. We leave it to future investigation.

Daily trading volume is not very large, € 310 mln, and it is exceedingly variable. Daily trading frequency is equal to 48, on average, and average turnover is 2.9 per cent. On the BrokerTec platform, daily trading volume of the on-the-run 10-year maturity U.S. Treasury note is $ 27,143 mln, more than 60 times the trading volume on the MTS platform. The corresponding daily trading frequency is 10,335. On the Canadian IDB market, daily trading volume of the on-the-run 10-year maturity Government of Canada bond amounts to $ 193 mln, and daily trade frequency is equal to 42. In conclusion, the trading activity on MTS is much smaller that the trading activity on one of the corresponding IDB electronic platform in U.S.. Nevertheless, the liquidity supplied by the order book on MTS seems to be relevant, and adequate for the market needs, even though smaller than the liquidity on the U.S. IBD market.

Finally, the last panel of Figure 6.1 shows *absolute price change* is lower in the first half of the day and it switches to a higher level after 2:00 p.m..

[63] The Cost of the round trip for an amount of € 25 mln shows a mean only slightly larger than the mean of CRT10 and even a smaller standard deviation.

Table 6.2 – Summary statistics for trading measures

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
trading volume	310.01	177.63	185.72	275.32	403.05	9.94	1054.51
trading frequency	47.59	26.97	28	42	63	1	156
turnover	2.85	2.45	1.31	2.13	3.51	0.08	19.62
tradesize	6.48	2.41	5	5	10	0.5	45
Panel B: off-the-run							
trading volume	176.51	142.20	83.35	144.57	230.95	4.92	1739.55
trading frequency	24.88	19.72	12	21	33	1	231
turnover	0.82	0.67	0.38	0.66	1.07	0.02	7.10
tradesize	6.90	2.51	5	5	10	1	35

Note: The table report summary statistics for the 10 year BTPs' database. Trading volume, trading frequency and turnover are computed at a daily frequency; trade size is computed without time aggregation, i.e. on all the contracts in the sample. Panel A refers to on-the-run and Panel B to off-the-run issues. "p" is the p-th percentile of the distribution. Trading volume is expressed in millions of euros, turnover is expressed as a percentage, trading frequency and trade size are pure numbers.

Table 6.3 – Summary statistics for trade size

	tradesize	mean	sd	Perc.	Cum.
	2.5			60.47	60.47
	5			38.62	99.09
BTP 30	10	3.54	1.50	0.48	99.57
	25			0.04	99.61
	other			0.39	100
	2.5			0.35	0.35
	5			66.61	66.96
BTP 10	10	6.67	2.47	32.68	99.64
	25			0.03	99.67
	other			0.33	100
	2.5			12.29	12.29
	5			59.74	72.03
BTP 5	10	6.10	2.63	27.17	99.2
	25			0.04	99.24
	other			0.76	100
	2.5			3.28	3.28
	5			59.67	62.95
BTP 3	10	6.90	3.11	35.74	98.69
	25			0.22	98.91
	other			1.09	100
	2.5			71.37	71.37
	5			14.11	85.48
CTZ	10	4.03	3.39	11.33	96.81
	25			0.16	96.97
	other			3.03	100
	2.5			33.05	33.05
	5			29.66	62.71
BTP 10 ind	10	6.00	3.26	35.47	98.18
	25			0.05	98.23
	other			1.77	100

Note: The table reports trade size (in mln of euros) statistics for all the securities and all the contracts in the sample.

6.2 The price impact approach

Although the descriptive analysis of the previous sections may provide an exhaustive picture of the Italian market liquidity, it is worthwhile to examine in a deeper way the price impact measures. As pointed out before, a liquid market is a market where participants can rapidly execute large-volume transactions with a small impact on prices. In particular, we expect that buy-trades generate a positive impact and sell-trades a negative impact on prices. The intuition is that directional trades will be associated with a larger movement in prices when markets are illiquid. The price impact coefficient from the Kyle model relates net trading activity to price changes.

Indeed, Kyle (1985) develops a dynamic model of insider trading to study the informational content of prices, the liquidity characteristics of a speculative market, and the value of private information to an insider. The model is able to characterize how an informed trader would transact in order to maximize the value of private information. The price impact coefficient in the model reflects how much the market adjusts prices to reflect the information content of trades and, as a consequence, it can be used to characterize the liquidity of financial markets. Although the price impact does not measure directly the resiliency of the market, it provides a measure of how much prices move in response to a trade. Hence, lower price impact coefficients imply more liquid markets. Following Fleming (2003), we now estimate on the whole sample four specifications of the model presented in section 3.2 in order to provide a general assessment of the liquidity of the Italian wholesale secondary Treasury security market.

Table 6.4 – Price impact of trades for the 10 year BTPs

Panel A

	(1)	(2)	(3)	(4)
net trading count	0.0018***		0.0030***	
net trading quantity		0.00023***	-0.0002**	
# buy				0.00162***
# sell				-0.00199***
constant	-0.00013	-0.00007	-0.00017	0.00023
N	16,493	16,493	16,493	16,493
Adjusted R^2	0.025	0.022	0.026	0.025

Panel B

	N	mean	sd	p25	p50	p75	min	max
price change	16,493	3.9E-05	0.027	-0.013	0	0.014	-0.314	0.212
net trading count	16,623	0.09	2.40	-1	0	1	-29	39
net trading quantity	16,623	0.44	17.12	-5	0	5	-250	280
# buy	16,623	1.05	1.64	0	1	1	0	39
# sell	16,623	0.95	1.59	0	1	1	0	33

Note: Panel A reports the results of five-minute price change regression on various measure of trading activity over the same time interval for the on-the-run 10 year BTPs. Price changes are computed using midquotes. Net trading count is the number of buyer-initiated trades less the number of seller-initiated trades. Net trading volume is buyer-initiated less seller-initiated volume and is measured in millions of euros. Number of buy (sell) is the number of buyer (seller) - initiated trades. The sample period is January 1st, 2004 - November 13th, 2006. The stars specify the significance of coefficients: * p<.05; ** p<.01; *** p<.001. Heteroskedasticity-consistent standard errors are computed when the needed. Panel B reports summary statistics for the variables in the regressions.

Table 6.4 reports the results of the estimation procedure on the on-the-run 10-year coupon bonds[64]. In the first specification we regress price changes on the net number of trades. The regression coefficient is, as expected, positive and highly significant. The value of the coefficient is 0.0018, this means that about 6 contracts, net, move the price of 1 tick, i.e. of 0.01. The adjusted R^2 is about 0.025, meaning that just 2.5% of the variation in price changes is explained by the net trading count. The adjusted R^2 statistics are in general low if compared with the US ones by Fleming (2003). However, D'Souza et al. (2003) find for Canada comparable value for these statistics[65]. In specification (2) the independent variable is net trading volume, the coefficient is still positive but is lower in magnitude and in explanatory power with respect to specification (1). The coefficient indicates that we need about 43 millions of euros, net, to move the price of 1 tick[66]. In specification 3 we include both the net number and the net size of the trades. In this case the coefficient of the net trading quantity is negative. Hence, controlling for the number of trades, higher volume is associated with lower price changes. This is consistent with Fleming (2003) findings. In the last specification we use the number of buy and sell trades as regressors, we find similar coefficients but with the expected opposite signs. The results are amplified in magnitude if we consider off-the-run securities, in particular the constants are also significant and the explanatory power raises to about 4%. This seems to confirm that the market for off-the-run securities is less liquid with respect to the on-the-run one.

The estimation of the models is repeated for all the securities in the sample using, for the sake of comparability, yields changes instead of price changes as dependent variable. The results are displayed in Table 6.5, we report only the coefficients from specification (3)[67].

Table 6.5 – Price impact coefficients for all the maturity segments

	BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
net trading count	0.01696***	0.00864***	0.01467***	0.02051***	0.01372***	0.05708***
net trading quantity	-0.00205**	-0.00044*	-0.00041	-0.0007**	-0.00068***	-0.0003
constant	-0.00286*	-0.00038	-0.00165	-0.00002	-0.00091	-0.01936*
N	3,527	15,600	8,792	11,745	14,542	1,301
Adjusted R^2	0.065	0.026	0.039	0.059	0.040	0.198

Note: The table reports the results of five-minute yield change regression on various measure of trading activity for on-the-run Treasury securities. Yield changes are computed using information about closing prices and modified durations. Net trading count is the number of buyer-initiated trades less the number of seller-initiated trades. Net trading volume is

[64] The estimation results for all the securities in the sample are included in the Appendix C.
[65] We computed the net trading count price impact coefficients in terms of prices in order to make a comparison among MTS Italy, US interdealer broker market, as in Fleming (2003), and Canadian interdealer broker market, as in D'Souza et al. (2003). The comparison, based on on-the-run 10 year bonds, shows a good degree of liquidity of MTS. The US and Canadian price impact coefficients are respectively two and seven times the coefficients estimated on MTS data.
[66] Interestingly, the estimated price impact is quite similar to the average value of the slope, which measures, in the order book, how far a trader has to move from the best quote, if he wants to trade € 100 mln.
[67] The estimation results for specifications (1), (2) and (4) are included in the Appendix C.

buyer-initiated less seller-initiated volume and is measured in millions of euros. The stars specify the significance of coefficients: * p<.05; ** p<.01; *** p<.001. Heteroskedasticity-consistent standard errors are computed when needed.

The coefficients, when significant, have the expected signs. The magnitude of the coefficients is higher for the less liquid segment, i.e. the index linked BTPs. This is not surprising. Overall, we can say that the 10-year index liked coupon bonds are characterized by lower trading activity and that trading activity, when occurs, has an impact on prices. The coefficients of net trading quantity are less significant than the coefficients on the net number of trades. For the very long segment of coupon bonds we observe a coefficient on the number of trades that is not very distant to the other BTPs, but we also find the highest coefficient for the size variable. This is probably due to the fact that trading in 30-year BTPs is characterized by non frequent contracts of small size and, as a result, low trading volume. The adjusted R^2 statistic seems to be a negative function of liquidity, it ranges from the 2.6% of the 10 year BTPs to the 19.8% of the index linked BTPs.

6.3 Comparison between liquidity measures

In this paragraph we computed the correlation coefficents among measures at 5-minute frequency and at weekly frequency. We included in the analysis the weekly estimation of the price impact coefficients. The correlation analysis will allow us, first, to better understand the degree of liquidity of the order book, second, to select a list of indicators that give a comprehensive description of the most important features of order book and trading data.

Table 6.7 and Table 6.8 at the end of the section contain correlation coefficients for the on-the-run 10 year BTPs[68]. As in Fleming (2003) we include the set of trading measures only in the table at weekly frequency because they have a smoother behaviour at this frequency. Summary statistics at weekly frequency of all the measures are reported in Table 6.6.

The presentation of the empirical evidence will follow a triangular structure. We will first present the reciprocal correlation among market condition indicators. Second, we will comment the reciprocal correlations among tightness indicators, and their correlations with market condition indicators. Afterwards, we will show the reciprocal correlations among depth indicators, and their correlations with market condition and tightness indicators and so on. In other words, any time we comment a new class of indicators, we analyse the correlation of those indicators with the ones previously presented.

[68] The tables for the remaining securities are displayed in the Appendix C.

6.3.1 Market conditions

The correlation of all our liquidity measures with indicators of market conditions will allow us to evaluate the reaction of the order book and of trading activity to changes in the trading environment. The two indicators we will focus on are the number of market participants and price volatility. The former indicator measures the degree of competition among market makers. The latter mainly catches the process of price discovery. When news hit the market, they are incorporated into prices and cause an increase of price volatility. In this process, asymmetries of information may have a central role and determine the behaviour of traders and market makers. A large literature on price discovery in the presence of asymmetric information has shown that trading data, in particular order flows, convey information and contribute to determine prices. On the contrary, the role of order book data in the process of price discovery has not been explored to a great extent[69]. Investigating the connection between order book and price discovery is beyond the scope of the present research. However, our correlation analysis can be considered as a preliminary step towards further research. In this framework, we will be unable to identify casual relationships. Nevertheless, our descriptive analysis will allow us to highlight interesting co-movements among order book data, trading data and price volatility.

We are aware, however, that both the number of market participants and price volatility can not be considered as exogenous variables. In effect, the decision of the dealers to participate to the market is taken together with the decisions on their proposals about prices and quantity. Therefore, the interpretation of the number of participation is not unambiguous. The endogeneity of the number of participants is confirmed by its negative correlation, -0.23, with price volatility at 5-minute frequency. In periods of high volatility, when asymmetric information is presumably higher, some market makers temporarily leave the market in order to reduce the risk of adverse selection[70]. This pattern is clearly shown in Figure 6.1. Furthermore, price volatility depends on trading activity, as mentioned above, and, therefore it is an endogenous variable. However, we will consider it as an indicator of uncertainty on the true value of the security.

6.3.2 Tightness

The increase in price volatility makes spreads larger. Information uncertainty turns the market makers more cautious. The effect is particularly evident on weekly data. Evidently, price

[69] Campbell and Hendry (2007), Mizrach and Neely (2005), Green (2004), Brandt and Kavajecz (2004) examine the price discovery process on the US government security market. Cheung, de Jong and Rindi (2005), Menkveld, Cheung and de Jong (2005), Beber, Brandt and Kavajecz (2007) study the price discovery process on the euro sovereign debt market. Fleming and Mizrach (2007) explore the role of order book data on the price discovery process on the US government security market.

[70] At weekly frequency the correlation is smaller and not statistically significant. Evidently, the decision of leaving the market is always temporary.

volatility modifies the behaviour of market makers especially when it is persistent. Furthermore, when the number of market participants rises, best spread and weighted spread fall, which is particularly evident in the former case. This is true even on weekly frequency and, therefore, it is not caused by the variability of the number of operators along the day. Evidently, the number of participants is truly a measure of market competition. On the contrary, only weak correlation is detected between spread and number of market participants at 5-minute frequency.

6.3.2 Depth

Total quote size is positively correlated with all the other measures of size. However, the magnitude it is very high only with second size, average size and weighted depth. Evidently, when quote size changes, its variations are not uniformly distributed on the order book[71]. Furthermore, both at 5-minute frequency and at weekly frequency best and worst size are negatively correlated. This confirms that quote size is not uniformly distributed, and makes it interesting to explore the divergent behaviour of best and worst size. At 5-minute frequency the quote size per operator is either weakly and positively correlated or uncorrelated with the other measures of quote size. This confirms that the amount quoted by each dealer is quite stable; most of the variability of total quote size comes from the number of dealers who participate in the market. At weekly frequency, however, quote size per participant is highly and positively correlated with all the other measures of size[72]. At 5-minute frequency when price volatility increases all the quote size measures worsen but the quote size per operator. Therefore, as expected, a jump in price uncertainty causes a rise in spreads and a fall in quote size. However, the impact of volatility on the order book is only temporary. In effect, on weekly data no clear evidence of correlation between volatility and trade measures is present.

The analysis of the correlation between depth measures and best spread casts new light on the quality of the order book and on the distribution of quote size. At weekly frequency, best spread is negatively correlated with all the measures of depth. This shows the consistency between best spread and size measures: When best spread shows higher market liquidity, quote size measures point to the same direction. However, data at 5-minute frequency hide a surprise: the correlation between best size and best spread becomes positive[73]. This means that when the market becomes more liquid and quote size increases and best spread shrinks, quote size at the best prices falls.

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[71] See note 59 for similar evidence, based on the comparison between hours of trade concentration and rest of the day. However, a low correlation coefficient between total quantity and best size is found even in the hours of trade concentration.

[72] Notice, however, that most of the variability of size measures is concentrated at 5-minute frequency. Table 5.6 shows that the coefficient of variations at weekly frequency of quote size amounts to 0.11, whereas at 5-minute frequency the same coefficient was 0.40.

[73] The correlation becomes even larger in the hours of trade concentration.

Therefore, the behaviour of best size is peculiar: it is not strongly correlated with total quote size and it is inconsistent with best spread.

Finally, the correlations between depth measures and the other two measures of spread tell us something interesting about the differences among spread measures. At 5-minute frequency the correlations between weighted spread and total quote size is small, the correlation between weighted spread and best size has the opposite sign with respect to the correlation of best spread, and the correlation coefficients between spread and all the size measures are close to zero.

6.3.4 Breadth

In the previous section we already pointed out that the behaviour of steepness during the day is at odds with the behaviour of spread and size measures. Correlation analysis confirms it, steepness increases when best spread falls and quote size rises. How can the rise of steepness at moments when the market seems to be more liquid be explained? The analysis of simple correlations provides interesting insights, even though it does not allow to answer thoroughly this question. At 5-minute frequency data show relevant correlation of steepness with the number of market makers, 0.51, with total quote size, 0.48, and with worst size, 0.73. That evidence seems to be connected with the evolution of the order book during the day: in the hours of trade concentration, when the number of market makers increases, quote size increases, but it is not distributed uniformly over the quotes. On the contrary, the off-the-best quotes are the most affected by the additional quote size. Furthermore, new quotes are added at end of the order book, and this makes the order book steeper. This phenomenon is connected to the evolution of the order book throughout the day. In effect, on weekly data those correlations disappear. However, when the attention is focused only on the hours of trade concentration, another interesting evidence comes out: the correlation of steepness with quote size and market participants is low, and the tightening of best spread is not accompanied by an increase in best size.

Finally, the peculiar behaviour of steepness and the low quality of the order book help us to find an interpretation of the different behaviour of tightness measures. Both at 5-minute and at weekly frequency simple spread and weighted spread have a large and positive correlation with steepness. Behind the inconsistent behaviour of spreads there is simple algebra. The computation of both spread and weighted spread draws on all the quotes in the order book. As a consequence, if steepness increases and best spread does not move, both the simple and the weighted average of bid quotes fall and, at the same time, both the simple and the weighted average of the ask quote rise.

This explains the algebraic positive relationship of steepness with both spread and weighted spread[74].

6.3.5 Multidimensional Measures

Slope behaves consistently with the other measures of liquidity and it decreases when best spread tightens, or when total quote size and best size increase. Furthermore, the increase of the number of market makers is associated with a drop in the slope, as the other liquidity measures do; and when price volatility rises, slope tends to rise as well, at least at 5-minute frequency. As to the differences among slope, DS and DSS, our evidence shows their similar correlation coefficients. Given that slope is easier to compute and it is available on a real-time basis, we definitively prefer it to the others.

Both market quality index and CRT turn up to be good synthetic indicators of market liquidity. They show the expected correlation with spreads, quote size measures, slope, market participants and volatility, even though the effect of volatility on liquidity is only temporary, as usual. Furthermore, they are reciprocally consistent: when market quality index improves, the CRT falls. CRT shows a positive correlation with best size at 5-minute frequency. This means that when best size rises the cost of round trip increases, and the two liquidity indicators point at different directions. The evidence has reasonably to be related to the positive correlation between best size and best spread: given that larger best size is associated to a larger best spread, a positive correlation between best spread and CRT turns out. In effect, at weekly frequency, when the correlation between best spread and best size changes sign, the same occurs to the correlation between CRT and best size. Furthermore, at 5-minute frequency market quality index is only slightly correlated with steepness, and this is good, given the behaviour of steepness. However, CRT is negatively and quite strongly correlated with steepness, and this adds up to the previous evidence about contradictory outcomes of steepness with respect to other liquidity measures. At weekly frequency, however, a switch occurs and CRT shows almost no correlation with steepness and, on the contrary, market quality index exhibits a strong negative correlation coefficient.

6.3.6 Trading measures

Trading measures show the expected reciprocal correlations. A larger trade volume is combined with larger turnover and smaller price impact coefficients[75]. Furthermore, trade size

[74] Actually, the link between spreads and steepness is complicated by the evidence of a negative correlation between best spread and steepness. Therefore, as steepness rises, simple and weighted spread are affected by two opposite effects: On one hand, the best spread fall tends to shrink them; on the other hand, the steepness rise enlarges them. Evidently, the latter effect prevails on the former.

[75] On the off-the-run securities, though, the correlations between trade volume and price impact coefficients are small and not significantly different from nil.

confirms to be quite constant and not very affected by market evolution: it is not significantly correlated with trading volume. As a consequence, trading frequency is highly correlated with trading volume. However, the relevant issue is: Are the trading measures consistent with order book measures? No clear and general relationship emerges between trading and order book measures. For instance, trading volume and trading frequency have no significant correlation with spread measures. However, an increase in trading frequency or in turnover has a negative impact on most of the quote size measures, the number of market participants, the steepness and the slope of the order book, and the market quality index[76]. On the contrary, an increase in trade size or a fall in the price impact coefficients is combined with tighter spreads, larger quote size and market participants, reduced steepness and slope, a higher market quality index.

Table 6.6 – Weekly summary statistics

	N	mean	sd	p25	p50	p75	min	max
best spread	145	0.025	0.002	0.023	0.025	0.026	0.020	0.034
spread	145	0.049	0.003	0.047	0.049	0.051	0.042	0.063
weighted spread	145	0.046	0.003	0.044	0.045	0.048	0.040	0.060
best size	145	37.10	5.64	34	37.7	41	19.5	50
second size	145	74.98	12.02	68	75.1	83.0	34.25	101
worst size	145	46.49	9.85	39.1	47	54	17	73
quote size	145	156.45	16.94	147.2	158	167	98	200
average quote size	145	45.25	6.03	41.3	46	49	23.78	58.6
weighted depth	145	88.38	10.69	82.31	90.19	95.55	49	115.5
qte size per partic.	145	8.16	0.58	7.77	8.10	8.42	7	10.4
steepness	145	0.03	0.00	0.02	0.03	0.03	0.02	0.03
slope	145	0.03	0.00	0.03	0.03	0.03	0.02	0.1
DS	145	3.50	0.67	3.05	3.29	3.76	2.55	7.14
DSS	145	0.0004	0.0001	0.0003	0.0004	0.0004	0.0003	0.001
mkt quality index	145	9.41	1.65	8.18	9.64	10.41	3.94	13.13
CRT 10	145	0.03	0.00	0.02	0.02	0.03	0.02	0.03
abs price change	145	0.01	0.00	0.0129	0.01459	0.01604	0.00831	0.023
mkt participants	145	19.26	1.56	18.61	19.43	20.33	13.71	22.26
trade size	145	6.50	0.47	6.11	6.52	6.91	5.45	7.49
trading volume	145	368.91	128.44	281.68	355.54	446.47	99.84	678.91
trading frequency	145	56.60	19.70	40.88	55.17	68.69	16.38	106.41
turnover ratio	145	3.36	2.20	1.81	2.61	4.25	0.55	12.65
NTQ	145	0.0003	0.0003	0.0002	0.0003	0.0005	-0.0006	0.0014
NTC	145	0.0025	0.0021	0.0011	0.0021	0.0037	-0.0033	0.0101

Note: The table report summary statistics for the 10 year on-the-run BTPs' database at a weekly frequency. NTQ and NTC are the price impact coefficients coming from weekly regression of five-minute price change on respectively the net trading quantity and the net number of trades over the same time interval. Price changes are computed using midquotes and are measured in terms of prices. "p" is the p-th percentile of the distribution.

[76] No significant correlation is found between trading frequency and order book measures on the off-the-run securities, though.

Table 6.7 – Correlations at a 5-minute frequency

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*	*DS*	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*
best spread	1																
spread	0.6789*	1															
weighted spread	0.7019*	0.8433*	1														
best size	0.1988*	0.1799*	-0.1382*	1													
second size	-0.2475*	-0.0041	-0.1857*	0.2479*	1												
worst size	-0.6980*	-0.0224*	0.0814*	-0.2026*	0.3168*	1											
quote size	-0.4081*	0.0142*	-0.1626*	0.4471*	0.8523*	0.6334*	1										
average quote size	-0.2301*	-0.1177*	-0.2230*	0.6094*	0.8258*	0.3165*	0.8908*	1									
weighted depth	-0.1949*	0.0765*	-0.1897*	0.7479*	0.7791*	0.3126*	0.9215*	0.9302*	1								
qte size per partic.	-0.1121*	-0.1882*	-0.2258*	0.1124*	0.0661*	-0.0176*	0.0886*	0.1395*	0.1161*	1							
steepness	-0.5697*	0.3900*	0.1986*	-0.1603*	0.2659*	0.7279*	0.4770*	0.0566*	0.2311*	-0.1397*	1						
slope	0.4177*	0.1513*	0.1907*	-0.2247*	-0.6315*	-0.4322*	-0.6863*	-0.6526*	-0.6054*	-0.1165*	-0.3048*	1					
DS	0.2875*	-0.0377*	0.1673*	-0.2888*	-0.6422*	-0.3955*	-0.7092*	-0.6355*	-0.6498*	-0.0644*	-0.3447*	0.6480*	1				
DSS	0.3390*	0.1187*	0.2204*	-0.2180*	-0.5723*	-0.3507*	-0.4857*	-0.4698*	-0.4541*	-0.2593*	-0.2274*	0.7650*	0.6532*	1			
mkt quality index	-0.3188*	-0.3264*	-0.3204*	0.4603*	0.7596*	0.3132*	0.7939*	0.9491*	0.7978*	0.1768*	-0.0659*	-0.6242*	-0.5625*	-0.4393*	1		
CRT 10	0.9666*	0.5479*	0.5935*	0.2100*	-0.2847*	-0.6710*	-0.4433*	-0.2434*	-0.2134*	-0.0741*	-0.5355*	0.4615*	0.3114*	0.3473*	-0.3428*	1	
abs price change	0.1401*	0.0502*	0.1139*	-0.1069*	-0.1755*	-0.1174*	-0.2190*	-0.1973*	-0.2064*	-0.0028	-0.0932*	0.1565*	0.1452*	0.1383*	-0.1793*	0.1252*	1
mkt participants	-0.4006*	0.0403*	-0.1308*	0.4184*	0.8243*	0.6278*	0.9724*	0.8542*	0.8882*	-0.0930*	0.5066*	-0.6744*	-0.7015*	-0.4648*	0.7478*	-0.4257*	-0.2251*

Note: The table reports correlation coefficients for the 10 year on-the-run BTPs. The measures are calculated at a 5-minute frequency. The * indicates that the correlation coefficients are significant at the 5% level or better.

Table 6.8 – Weekly correlations

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*
best spread	1											
spread	0.6148*	1										
weighted spread	0.7115*	0.9262*	1									
best size	-0.2862*	-0.5840*	-0.7161*	1								
second size	-0.2266*	-0.6386*	-0.6501*	0.7891*	1							
worst size	-0.3014*	0.3863*	0.3460*	-0.2828*	-0.2874*	1						
quote size	-0.4602*	-0.4287*	-0.5094*	0.7325*	0.8041*	0.2972*	1					
average quote size	-0.2601*	-0.6979*	-0.6513*	0.8185*	0.9514*	-0.2072*	0.8286*	1				
weighted depth	-0.3859*	-0.5724*	-0.6608*	0.9031*	0.9089*	-0.0187	0.9430*	0.9235*	1			
qte size per partic.	-0.2900*	-0.3160*	-0.3523*	0.5828*	0.5767*	0.2350*	0.7382*	0.6258*	0.7046*	1		
steepness	-0.1091	0.6874*	0.5154*	-0.5127*	-0.5911*	0.6968*	-0.1701*	-0.6540*	-0.4066*	-0.2202*	1	
slope	0.4296*	0.6293*	0.5928*	-0.6443*	-0.7377*	-0.0864	-0.7922*	-0.8184*	-0.7956*	-0.5863*	0.4499*	1
DS	0.3591*	0.6220*	0.6628*	-0.7450*	-0.8423*	0.105	-0.7882*	-0.8420*	-0.8522*	-0.4915*	0.4468*	0.8797*
DSS	-0.3338*	-0.149	-0.1896*	0.0426	-0.0766	0.1847*	0.0718	-0.0295	0.0353	0.1271	0.103	-0.0876
mkt quality index	-0.3868*	-0.8362*	-0.7673*	0.7856*	0.8879*	-0.2760*	0.7323*	0.9533*	0.8498*	0.6024*	-0.7394*	-0.7875*
CRT 10	0.9507*	0.5768*	0.6759*	-0.3087*	-0.2013*	-0.3298*	-0.4590*	-0.2470*	-0.3865*	-0.3764*	-0.0495	0.4449*
abs price change	0.3082*	0.2579*	0.3393*	-0.1171	-0.0072	0.1602	0.0422	0.0107	-0.0229	0.0938	-0.0217	-0.0483
mkt participants	-0.4130*	-0.3659*	-0.4576*	0.5653*	0.6660*	0.1850*	0.7876*	0.6518*	0.7489*	0.1819*	-0.0855	-0.6685*
trade size	-0.0896	-0.3025*	-0.2956*	0.5163*	0.5849*	-0.0057	0.5724*	0.6010*	0.6002*	0.5951*	-0.3326*	-0.5021*
trad volume	-0.1266	-0.0173	-0.0527	-0.0331	-0.1182	0.043	-0.0672	-0.1092	-0.0722	0.0383	0.1091	0.0678
trad frequency	-0.102	0.0411	0.0101	-0.1670*	-0.2464*	0.0195	-0.2144*	-0.2473*	-0.2221*	-0.1305	0.1918*	0.1928*
turnover	-0.1242	0.2961*	0.3164*	-0.4791*	-0.5187*	0.4149*	-0.2781*	-0.4752*	-0.4273*	-0.0987	0.5008*	0.3270*
NTQ	-0.0787	0.1714*	0.1654*	-0.1849*	-0.2119*	0.3040*	-0.0328	-0.1912*	-0.1326	0.0796	0.2401*	0.0635
NTC	-0.0833	0.1539	0.1482	-0.1404	-0.1609	0.3237*	0.0299	-0.1345	-0.0737	0.1309	0.2143*	0.017

	DS	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*	*mkt partic.*	*trade size*	*trad volume*	*trad freq.*	*turnover*	*NTQ*	*NTC*
DS	1											
DSS	0.009	1										
mkt quality index	-0.7671*	0.0378	1									
CRT 10	0.3179*	-0.3660*	-0.4080*	1								
abs price change	0.0446	-0.1392	-0.0527	0.2557*	1							
mkt participants	-0.7498*	-0.0172	0.5386*	-0.3410*	-0.0078	1						
trade size	-0.4890*	0.1261	0.5603*	-0.1621	0.1613	0.3052*	1					
trad volume	0.0532	-0.0189	-0.0827	-0.1044	0.01	-0.1441	0.1258	1				
trad frequency	0.1572	-0.0415	-0.2194*	-0.0404	-0.0509	-0.2100*	-0.1099	0.9626*	1			
turnover	0.4538*	0.152	-0.4451*	-0.0797	0.0421	-0.3447*	-0.1997*	0.4039*	0.4601*	1		
NTQ	0.1537	-0.0091	-0.1810*	-0.1234	0.1800*	-0.1234	-0.2138*	-0.3607*	-0.3423*	-0.0323	1	
NTC	0.1075	0.0401	-0.132	-0.1317	0.2409*	-0.0808	-0.1182	-0.3638*	-0.3663*	-0.0502	0.9700*	1

Note: The table reports correlation coefficients for the 10 year on-the-run BTPs. The measures are calculated weekly. The * indicates that the correlation coefficients are significant at the 5% level or better.

6.4 Liquidity comparison across securities

In this section we perform a direct comparison of the liquidity measures across the securities in the sample. We focus on the on-the-run issues[77]. Since many measures are function of prices we need to exploit the relationship between prices and duration[78] to express these measures in yields. By doing so we make securities with different maturities reciprocally comparable. Conversely, the measures that depend only on the quoted quantities can be compared directly. In particular, best spread, quoted spread, weighted spread, steepness, slope, DS e DSS and absolute price change are

[77] In the Appendix C we include the statistics for the off-the-run issues.
[78] We use daily data on the modified duration provided by Bloomberg and Reuters.

divided by the product between the daily closing modified duration and the daily closing price. Market quality index is now simply the ratio between the average quote size and the yield version of the spread, and price impact coefficients, NTQ and NTC, have been estimated once again, after computing the dependent variable in terms of yields. We work out both summary statistics and correlation coefficients at weekly frequency.

6.4.1. Summary statistics

In the tables at the end of the section we compare the liquidity measures across the different maturity segments. Market volatility ranges from 0.0013 for the CTZs to the 0.002 for the 5-year BTPs. The number of market participants goes from 8.8 in the case of 10 year index linked BTPs, to 19.3 in the case of 10-year BTPs. CTZs and 30-year BTPs are in the lower side of this range.

With respect to best spread, the 10-year BTP is the most liquid security, followed by CTZs, 5-year BTPs, 30-year BTPs and 3-year BTPs. The 10-year index linked BTPs have the wider spread, and, in general, they have the worst performance whatever measure we consider. Surprisingly, the 30-year BTPs gains the fourth position. This result is robust if we look at the median of the distributions.

Turning to the depth measures, we note that the medium and long term BTPs quote larger quantities in the first two levels of the book and smaller in the rest of it. The very long term BTPs, the zero coupon bonds and the index linked bonds exhibit an opposite pattern and in general they have a lower quote size. Therefore, the less liquid segments have a quote size that is comparable to the most liquid segments, but the distribution of depth is more concentrated in the lower part of the book. This implies that quote size alone is not a good proxy of liquidity and we have to consider the depth position in the book. Focusing on the medium and long term BTPs, namely 3-5-10-year BTPs, the peculiar behaviour of depth measures turns up. Although the amount of quote size is comparable among the three securities, average quote size and quote size per participant is higher the shorter the maturity. For the 3-year BTPs the number of market participants is smaller than for the 10-year BTPs, however each of them, on average, posts an amount higher than the amount posted on the 10-year BTPs. Furthermore, the average quote size is higher on the 3-year then on 10-BTPs, and both best size and second size are larger on 3-year than on 10-year BTPs. In all the previous cases the 5-year stands between 3-year and 10-year BTPs. This evidence adds up to what we called the low quality of the order book. On the long side of the BTP market, tighter spreads are associated with smaller size on the top of the book, smaller quote size per market participant, smaller average quote size.

We included in our analysis the quote frequency, which is the number of different prices quoted[79] (Table 6.12). Quote frequency, which is usually a proxy of market activity, can be also interpreted as a measure of market breadth. In the medium and long term segment for the BTPs we find, on average, 3 quotes. This implies that the whole market is visible to each market participant through the MTS page that reports the best five quotes and the corresponding quantities. On the contrary, in the very long term BTP segment, i.e. the 30-year one, we have around two times the quotes of the other BTPs. Furthermore, the CTZs show on average 10 different quotes; hence, only half of the market is visible. The larger quote frequency for the CTZs is partly explained by the pricing conventions. In fact, the minimum price difference, i.e. the tick, is 0.01 for the BTPs and 0.001 for the CTZs. Evidently, a smaller tick size increases the quote frequency. However, quote frequency does not depend only by pricing conventions. The 10-year index linked BTPs are quoted in hundredths of one per cent of par, nevertheless, they also show a high quote frequency. Therefore, a high quote frequency also gives evidence of a lack of competition among market makers.

From the perspective of steepness, slope, DS and DSS, the 10-year BTPs show always the lower figures and then the higher liquidity. The 30-year BTPs confirm their good performances in that they have the second lowest steepness and slope. The zero coupon and the index linked bonds achieve the worst values, this is partly due to their less concentrated book. In general, these measures provide similar information. It is interesting to note that the steepness, that in the previous sections we proved to be not a good proxy of liquidity, here behaves correctly, that is, it is smaller for the most liquid securities. This is an indirect proof of the importance of the correlation analysis as a tool to distinguish the most informative measures of liquidity. The last measure in the table is a variation of the market quality index, and we call it market quality index 2. In particular at the numerator we substitute the average quote size with the quote size. The aim of the new measure is to allow a better comparison of market quality index across securities. In effect, CTZs are characterized by larger quote frequency, and, as a consequence, smaller average quote size and smaller values of the usual market quality index. The 10-year BTPs show the higher value of market quality index 2, followed by the 5-year and the 3-year BTPs. The 30-year BTPs and CTZs show values of the index that are one third of the 10-year ones. The index linked bonds perform even worse.

Let us finally consider our measures of trading. As expected the 10-year BTPs show the best performances in terms of volumes and contracts. Moreover, trading in these securities produces a lower impact on prices. This point is particularly evident: trading in the 5-year and 3-year BTPs

[79] Quote frequency matches with quote frequency in D'Souza and Gaa (2004) and corresponds to $\frac{n_{ask}+n_{bid}}{2}$.

produces price impacts that are twice the 10-year BTPs ones. The difference with respect to the other securities is even larger. The 3-year BTPs are characterized by contracts that are less frequent but with higher mean trade size and higher price impact with respect to the 10-year and 5-year BTPs. CTZs are traded frequently and with small trade size, this could be a signal of the fact that this kind of securities is considered as a monetary instrument. The other trading variables exhibit values, in the case of CTZs, that are close to the ones shown by medium and short term BTPs. The 30-year BTPs are traded twice as frequently as the 10-years index linked BTPs are, but for half of the size. As a result trading volume and turnover ratio are very similar for these segments. The index linked securities are the less traded, and they show price impact coefficients that are between six and seven times the 10-year BTPs ones. To sum up, the medium and long term BTPs seem to represent the most liquid segments.

Till now we have focused on the on-the-run securities. As a robustness check we now consider the difference between on-the-run and off-run securities. It turns out that this difference is always small[80]. In general, we have that the on-the-run securities show a higher liquidity in terms of order book measures. Indeed, these better performances are small in magnitude and they are clearer for the more complex measures that take into account both prices and quantities. With respect to the trade measures, the liquidity is higher for the on-the-run securities and this pattern is clearer for the 10-year and 3-year BTPs[81].

Table 6.9 – Comparison of market condition indicators across securities

		# obs.	mean	sd	p25	p50	p75	min	max
absolute price change	*BTP 30*	102	0.0019	0.0003	0.0016	0.0018	0.0020	0.0011	0.0028
	BTP 10	139	0.0018	0.0003	0.0016	0.0017	0.0019	0.0010	0.0030
	BTP 5	132	0.0020	0.0005	0.0017	0.0020	0.0022	0.0012	0.0037
	BTP 3	153	0.0017	0.0003	0.0015	0.0017	0.0019	0.0011	0.0027
	CTZ	142	0.0013	0.0003	0.0011	0.0013	0.0016	0.0006	0.0021
	BTP 10 ind	82	0.0019	0.0003	0.0017	0.0019	0.0021	0.0012	0.0029
market particip.	*BTP 30*	102	10.65	1.06	10.07	10.75	11.34	7.07	12.44
	BTP 10	145	19.26	1.56	18.61	19.43	20.33	13.71	22.26
	BTP 5	134	17.02	3.07	14.59	17.18	19.76	8.18	22.21
	BTP 3	154	13.77	1.36	12.94	13.95	14.65	6.80	16.28
	CTZ	144	12.41	1.74	11.83	12.70	13.38	1.02	15.07
	BTP 10 ind	103	8.78	0.73	8.38	8.79	9.21	5.07	10.52

Note: The measures are calculated weekly as mean quote frequency, mean five-minute absolute price change and mean number of market participants of the on-the-run securities. "p" is the p-th percentile of the distribution.

80 The tables regarding the off-the-run sample are included in Appendix C.
81 The comparison between on-the-run and off-the-run will be further developed in section 7.

Table 6.10 – Comparison of tightness measures across securities

		# obs.	mean	sd	p25	p50	p75	min	max
best spread	*BTP 30*	102	0.0062	0.0009	0.0056	0.0062	0.0069	0.0043	0.0082
	BTP 10	139	0.0031	0.0003	0.0028	0.0030	0.0033	0.0024	0.0041
	BTP 5	132	0.0053	0.0008	0.0047	0.0052	0.0058	0.0041	0.0101
	BTP 3	153	0.0071	0.0010	0.0065	0.0070	0.0075	0.0052	0.0128
	CTZ	142	0.0042	0.0010	0.0034	0.0039	0.0047	0.0026	0.0074
	BTP 10 ind	82	0.0125	0.0021	0.0114	0.0125	0.0140	0.0080	0.0172
spread	*BTP 30*	102	0.0102	0.0011	0.0093	0.0101	0.0108	0.0082	0.0124
	BTP 10	139	0.0061	0.0004	0.0058	0.0061	0.0064	0.0053	0.0071
	BTP 5	132	0.0101	0.0010	0.0094	0.0098	0.0109	0.0081	0.0138
	BTP 3	153	0.0142	0.0015	0.0134	0.0142	0.0148	0.0115	0.0243
	CTZ	142	0.0131	0.0021	0.0114	0.0131	0.0144	0.0089	0.0216
	BTP 10 ind	82	0.0235	0.0020	0.0228	0.0240	0.0249	0.0188	0.0272
weighted spread	*BTP 30*	102	0.0098	0.0011	0.0089	0.0096	0.0104	0.0078	0.0123
	BTP 10	139	0.0057	0.0004	0.0053	0.0056	0.0059	0.0050	0.0067
	BTP 5	132	0.0093	0.0009	0.0087	0.0092	0.0101	0.0074	0.0118
	BTP 3	153	0.0135	0.0014	0.0125	0.0134	0.0140	0.0108	0.0227
	CTZ	142	0.0112	0.0017	0.0098	0.0110	0.0123	0.0080	0.0162
	BTP 10 ind	82	0.0239	0.0020	0.0232	0.0243	0.0253	0.0189	0.0268

Note: The measures are calculated weekly as mean best spread, mean quoted spread, mean weighted spread of the on-the-run securities. "p" is the p-th percentile of the distribution.

Table 6.11 – Comparison of depth measures across securities

		# obs.	mean	sd	p25	p50	p75	min	max
best size	*BTP 30*	102	7.54	0.80	7.03	7.45	7.99	5.31	9.60
	BTP 10	145	37.10	5.64	33.64	37.69	41.15	19.53	50.34
	BTP 5	134	45.17	7.07	41.26	45.68	50.30	25.26	62.15
	BTP 3	154	52.24	9.96	45.93	53.28	59.39	20.53	75.69
	CTZ	144	10.28	3.87	8.40	9.96	11.23	5.73	48.25
	BTP 10 ind	103	10.76	1.18	9.93	10.61	11.27	8.58	14.81
second size	*BTP 30*	102	11.93	2.149	10.317	11.73	13.12	7.107	18.324
	BTP 10	145	74.98	12.02	68.15	75.11	83.02	34.25	101.04
	BTP 5	134	88.60	13.61	82.02	88.71	94.87	36.04	120.56
	BTP 3	154	96.03	13.41	88.36	96.99	104.3	26.22	129.49
	CTZ	143	12.61	4.14	10.12	11.99	13.94	6.56	28.12
	BTP 10 ind	103	13.81	1.902	12.641	13.67	14.94	10.38	23.22
worst size	*BTP 30*	102	66.18	8.50	62.54	67.35	71.41	37.43	82.55
	BTP 10	145	46.49	9.85	39.10	46.62	53.64	16.62	73.34
	BTP 5	134	23.54	5.80	19.45	22.34	27.44	11.24	38.56
	BTP 3	154	17.26	4.65	13.95	16.47	20.37	7.79	29.76
	CTZ	143	86.58	12.76	79.16	85.32	94.71	29.58	124.81
	BTP 10 ind	103	103.96	11.42	98.13	104.23	111.22	44.55	126.49
quoted size	*BTP 30*	102	82.68	9.95	78.27	83.50	89.93	53.04	98.28
	BTP 10	145	156.45	16.94	147.17	157.60	167.02	97.72	200.23
	BTP 5	134	155.12	18.66	146.18	155.25	165.95	79.71	199.29
	BTP 3	154	163.66	20.69	149.92	167.41	177.47	72.48	208.81
	CTZ	144	107.95	17.68	98.67	108.70	117.31	9.62	170.49
	BTP 10 ind	103	127.21	12.00	121.10	127.48	134.77	62.90	152.18
average quote size	*BTP 30*	102	11.61	1.20	10.97	11.61	12.53	7.83	14.40
	BTP 10	145	45.25	6.03	41.30	45.86	49.15	23.78	58.58
	BTP 5	134	52.90	8.71	47.45	53.60	58.62	26.22	74.50
	BTP 3	154	62.25	10.19	56.41	63.12	69.03	21.52	85.28
	CTZ	143	10.59	2.07	9.36	10.36	11.58	6.78	21.36
	BTP 10 ind	103	15.42	1.01	14.80	15.36	16.04	11.37	17.93
qtd size per participant	*BTP 30*	102	7.59	0.35	7.39	7.60	7.82	6.59	8.64
	BTP 10	145	8.16	0.58	7.77	8.10	8.42	6.58	10.41
	BTP 5	134	9.35	1.63	8.07	9.06	11.03	6.13	12.11
	BTP 3	154	11.91	0.68	11.59	11.93	12.30	9.58	13.92
	CTZ	143	8.92	1.08	8.17	8.80	9.63	6.79	13.32
	BTP 10 ind	103	14.42	0.57	14.10	14.46	14.79	11.91	15.52

Note: The measures are calculated weekly as mean beast size, mean second size, mean worst size, mean quoted size, mean average quote size, and mean quoted size per market participant of the on-the-run securities. “p” is the p-th percentile of the distribution.

Table 6.12 Comparison of breadth and multidimensional measures across securities

		# obs.	mean	sd	p25	p50	p75	min	max
steepness	*BTP 30*	102	0.0042	0.0008	0.0036	0.0041	0.0048	0.0030	0.0062
	BTP 10	139	0.0031	0.0003	0.0029	0.0031	0.0033	0.0022	0.0038
	BTP 5	132	0.0050	0.0005	0.0046	0.0049	0.0052	0.0039	0.0066
	BTP 3	153	0.0073	0.0008	0.0068	0.0073	0.0077	0.0056	0.0117
	CTZ	142	0.0113	0.0023	0.0096	0.0108	0.0124	0.0072	0.0204
	BTP 10 ind	82	0.0110	0.0017	0.0097	0.0106	0.0124	0.0075	0.0144
quote frequency	*BTP 30*	102	6.83	0.39	6.67	6.83	7.04	5.14	7.62
	BTP 10	145	3.46	0.25	3.31	3.49	3.63	2.69	4.18
	BTP 5	134	2.93	0.22	2.76	2.90	3.05	2.53	3.76
	BTP 3	154	2.70	0.19	2.57	2.67	2.76	2.32	3.43
	CTZ	144	10.13	1.39	9.47	10.27	10.82	0.72	13.31
	BTP 10 ind	103	8.16	0.60	7.85	8.22	8.57	5.21	9.22
slope	*BTP 30*	102	0.007	0.001	0.007	0.007	0.008	0.005	0.011
	BTP 10	139	0.004	0.001	0.003	0.004	0.004	0.003	0.006
	BTP 5	132	0.007	0.001	0.006	0.006	0.007	0.005	0.012
	BTP 3	153	0.009	0.002	0.008	0.009	0.010	0.006	0.020
	CTZ	142	0.014	0.003	0.011	0.013	0.016	0.008	0.029
	BTP 10 ind	82	0.012	0.002	0.011	0.012	0.013	0.010	0.027
DS	*BTP 30*	102	0.82	0.10	0.74	0.81	0.88	0.59	1.15
	BTP 10	139	0.43	0.08	0.38	0.41	0.47	0.31	0.71
	BTP 5	132	0.77	0.14	0.67	0.75	0.84	0.56	1.37
	BTP 3	153	1.27	0.25	1.12	1.24	1.41	0.79	2.28
	CTZ	142	7.49	1.89	6.00	7.16	8.90	4.22	11.75
	BTP 10 ind	82	1.22	0.13	1.14	1.20	1.30	0.99	1.84
DSS	*BTP 30*	102	0.0125	0.0024	0.0109	0.0119	0.0138	0.0090	0.0206
	BTP 10	139	0.0048	0.0012	0.0040	0.0046	0.0052	0.0030	0.0092
	BTP 5	128	0.0072	0.0024	0.0055	0.0067	0.0077	0.0042	0.0171
	BTP 3	153	0.0112	0.0059	0.0085	0.0097	0.0111	0.0058	0.0511
	CTZ	142	0.0195	0.0052	0.0156	0.0189	0.0230	0.0103	0.0385
	BTP 10 ind	82	0.0198	0.0032	0.0174	0.0199	0.0210	0.0153	0.0342
Market Quality Index 2	*BTP 30*	102	81.78	11.03	76.63	84.08	90.58	51.49	108.36
	BTP 10	139	259.67	37.30	233.04	261.51	286.76	164.10	353.91
	BTP 5	131	156.68	24.50	141.91	157.00	173.15	83.90	210.09
	BTP 3	153	116.88	16.08	105.80	117.38	129.88	69.77	147.85
	CTZ	142	86.40	20.12	70.44	82.26	101.37	42.15	136.66
	BTP 10 ind	82	55.17	7.83	50.76	53.63	58.25	24.69	74.51

Note: The measures are calculated weekly as mean steepness, mean slope, mean DS, mean DSS and mean market quality index 2 of the on-the-run securities. “p” is the p-th percentile of the distribution.

Table 6.13 – Comparison of trading measures across securities

		# obs.	mean	sd	p25	p50	p75	min	max
trade size	*BTP 30*	102	3.49	0.34	3.29	3.50	3.75	2.65	4.32
	BTP 10	145	6.50	0.47	6.11	6.52	6.91	5.45	7.49
	BTP 5	129	6.37	0.78	6.10	6.47	6.84	3.25	8.19
	BTP 3	154	6.94	0.82	6.34	6.98	7.50	4.87	9.17
	CTZ	143	4.00	0.81	3.53	3.84	4.29	2.81	9.70
	BTP 10 ind	101	6.12	1.24	5.56	6.01	6.76	2.50	10.00
trading volume	*BTP 30*	102	72.42	55.034	36.80	63.93	91.71	6.24	379.61
	BTP 10	145	368.91	128.44	281.68	355.54	446.47	99.84	678.91
	BTP 5	129	163.27	100.81	91.74	139.24	220.49	33.34	657.63
	BTP 3	154	223.53	143.96	131.74	183.65	275.2	45.36	1086.43
	CTZ	143	169.77	98.26	106.18	146.62	200.06	37.74	564.97
	BTP 10 ind	101	62.97	44.770	30.232	54.22	79.09	5.08	238.05
trading frequency	*BTP 30*	102	19.90	16.38	10.06	16.66	24.94	1.67	134.47
	BTP 10	145	56.60	19.70	40.88	55.17	68.69	16.38	106.41
	BTP 5	129	26.39	18.29	13.83	21.63	36.95	5.40	125.95
	BTP 3	154	32.59	22.31	18.20	26.20	39.16	6.48	193
	CTZ	143	43.63	22.65	28.40	39.22	50.39	9.90	128.91
	BTP 10 ind	101	9.99	6.95	5.20	8.57	12.62	1	37.28
turnover ratio	*BTP 30*	102	0.55	0.44	0.27	0.44	0.61	0.04	2.63
	BTP 10	145	3.36	2.20	1.81	2.61	4.25	0.55	12.65
	BTP 5	126	1.44	1.43	0.62	0.93	1.88	0.19	11.36
	BTP 3	154	2.22	2.94	0.92	1.39	2.36	0.28	27.16
	CTZ	143	2.08	2.43	0.87	1.37	2.43	0.31	18.22
	BTP 10 ind	101	0.56	0.52	0.21	0.42	0.65	0.04	3.51
NTQ	*BTP 30*	101	0.003	0.004	0.001	0.003	0.004	-0.013	0.018
	BTP 10	138	0.001	0.001	0.000	0.001	0.001	-0.002	0.005
	BTP 5	123	0.002	0.003	0.001	0.002	0.003	-0.008	0.018
	BTP 3	152	0.002	0.002	0.001	0.002	0.004	-0.003	0.008
	CTZ	140	0.003	0.003	0.001	0.002	0.004	-0.005	0.013
	BTP 10 ind	73	0.007	0.013	0.003	0.006	0.011	-0.072	0.039
NTC	*BTP 30*	101	0.010	0.014	0.004	0.011	0.017	-0.045	0.064
	BTP 10	138	0.008	0.007	0.004	0.006	0.011	-0.011	0.031
	BTP 5	123	0.016	0.019	0.006	0.014	0.022	-0.056	0.104
	BTP 3	152	0.019	0.016	0.011	0.018	0.027	-0.026	0.059
	CTZ	140	0.014	0.011	0.007	0.013	0.020	-0.015	0.055
	BTP 10 ind	73	0.050	0.066	0.028	0.044	0.081	-0.179	0.244

Note: The measures are calculated weekly as mean trade size, mean daily trading volume, mean daily trading frequency and mean daily turnover ratio of the on-the-run securities. NTQ and NTC come from the regression, using the on-the-run sample, of five minute price changes on respectively the difference between buy and sell quantities and buy and sell number of trades as regressor. “p” is the p-th percentile of the distribution.

6.4.2. Correlation analysis

Following D'Souza et al. (2003) we work out the correlation coefficients among the segments. For the sake of exposition we present the results only for a subset of our measures[82].

The absolute price change is, among all the measures, the one that shows the highest magnitude in the correlation coefficients. The coefficients are particularly high for the long and very long term segments. The participation in the market for the different segments is also positively correlated and significant.

Looking at the order book measures, we note that the 10-year BTPs are in general positively related with the other BTPs, the correlation coefficients are higher with the 30-year and 5-year BTPs for the spread and the slope variables and with the 3-year BTPs for the size measures. In general, the correlation coefficients are positive for the BTPs; this is consistent with the hypothesis of integration of these segments. However, as long as we consider the CTZs, we find negative and significant correlation coefficients between them and the 5-year BTPs in the spread measures and in the quote size per participant. The coefficients are negative, but not significant, if we look at trading volume and trading frequency.

The coefficients regarding the trading measures are always positive when significant, the relationships are stronger among the BTPs. This is consistent with the previous findings. The price impact measures more often exhibit significant correlations[83]. The index linked bonds are scarcely related to the other securities in the sample.

[82] The remaining tables are available in Appendix C.

[83] With respect to the variables not included in this paragraph, the second size and quoted size measures show positive and significant correlations. The worst size and the quote size per participant are positive when significant. The slope, DS and DSS measures seldom are significant.

Table 6.14 Correlations of market condition indicators across securities

		BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
absolute price change	*BTP 30*	1					
	BTP 10	0.9732*	1				
	BTP 5	0.6644*	0.6963*	1			
	BTP 3	0.6961*	0.6473*	0.6527*	1		
	CTZ	0.6027*	0.4560*	0.5158*	0.7801*	1	
	BTP 10 ind	0.9527*	0.9565*	0.6455*	0.7595*	0.6986*	1
market particip.	*BTP 30*	1					
	BTP 10	0.4675*	1				
	BTP 5	0.4466*	0.4473*	1			
	BTP 3	0.6289*	0.6311*	0.5675*	1		
	CTZ	0.4167*	0.4019*	0.4765*	0.4396*	1	
	BTP 10 ind	0.5629*	0.4903*	0.5361*	0.5562*	0.3955*	1

Note: The table reports correlation coefficients for on-the-run securities. The measures are calculated weekly as mean absolute price change and mean market participants. The * indicates that the correlation coefficients are significant at the 5% level or better.

Table 6.15 Correlations of order book measures across securities

		BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
best spread	*BTP 30*	1					
	BTP 10	0.4930*	1				
	BTP 5	0.2902*	0.4755*	1			
	BTP 3	0.4140*	0.3791*	0.4547*	1		
	CTZ	-0.0518	-0.15	-0.3013*	-0.02	1	
	BTP 10 ind	0.0752	0.20	0.00	0.20	0.5577*	1
spread	*BTP 30*	1					
	BTP 10	0.3759*	1				
	BTP 5	0.3620*	0.3320*	1			
	BTP 3	0.2508*	0.2893*	0.4401*	1		
	CTZ	-0.2991*	0.14	-0.13	-0.09	1	
	BTP 10 ind	0.2036	0.5148*	0.04	0.12	0.2774*	1
best size	*BTP 30*	1					
	BTP 10	0.5030*	1				
	BTP 5	0.4477*	0.5100*	1			
	BTP 3	0.4022*	0.6468*	0.4946*	1		
	CTZ	0.2824*	0.5451*	0.2056*	0.3158*	1	
	BTP 10 ind	0.1874	0.1613	0.2253*	0.2052*	0.3023*	1
average quote size	*BTP 30*	1					
	BTP 10	0.2623*	1				
	BTP 5	0.2598*	0.4695*	1			
	BTP 3	0.3265*	0.6476*	0.4829*	1		
	CTZ	0.4634*	0.4545*	0.2926*	0.4930*	1	
	BTP 10 ind	0.1638	0.137	0.1864	0.2068*	0.3036*	1
steepness	*BTP 30*	1					
	BTP 10	0.3039*	1				
	BTP 5	0.3250*	0.1281	1			
	BTP 3	0.1581	0.2136*	0.2352*	1		
	CTZ	-0.1474	-0.1027	0.0049	-0.1116	1	
	BTP 10 ind	0.7543*	0.3812*	0.1457	-0.0613	0.0928	1
DS	*BTP 30*	1					
	BTP 10	0.183	1				
	BTP 5	0.3965*	0.5117*	1			
	BTP 3	0.3259*	0.2608*	0.2855*	1		
	CTZ	0.3596*	0.1332	0.3716*	0.3221*	1	
	BTP 10 ind	0.0138	0.4713*	0.4809*	0.21	0.3169*	1

Note: The table reports correlation coefficients for on-the-run securities. The measures are calculated weekly as mean absolute price change and mean market participants. The * indicates that the correlation coefficients are significant at the 5% level or better.

Table 6.16 Correlations of trading measures across securities

		BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
	BTP 30	1					
	BTP 10	0.1248	1				
trading	*BTP 5*	0.2376*	0.0603	1			
volume	*BTP 3*	0.0661	0.1674*	0.2249*	1		
	CTZ	0.0064	0.0791	-0.0359	0.1682*	1	
	BTP 10 ind	0.0558	-0.0529	0.2145*	0.0399	0.0191	1
	BTP 30	1					
	BTP 10	0.2121*	1				
	BTP 5	0.0584	0.0766	1			
NTQ	*BTP 3*	0.3481*	0.2496*	0.0158	1		
	CTZ	0.2756*	0.0069	0.1163	0.2727*	1	
	BTP 10 ind	0.0199	-0.0334	-0.0753	0.0604	0.114	1
	BTP 30	1					
	BTP 10	0.2586*	1				
NTC	*BTP 5*	0.0895	0.1428	1			
	BTP 3	0.4399*	0.2667*	0.0726	1		
	CTZ	0.2623*	0.1479	0.1591	0.3273*	1	
	BTP 10 ind	0.0959	0.0099	-0.1163	0.1429	0.1124	1

Note: The table reports correlation coefficients for on-the-run securities. The measures are calculated weekly as mean absolute price change and mean market participants. The * indicates that the correlation coefficients are significant at the 5% level or better.

7. Exploiting the Liquidity Measures: The Benchmark Analysis

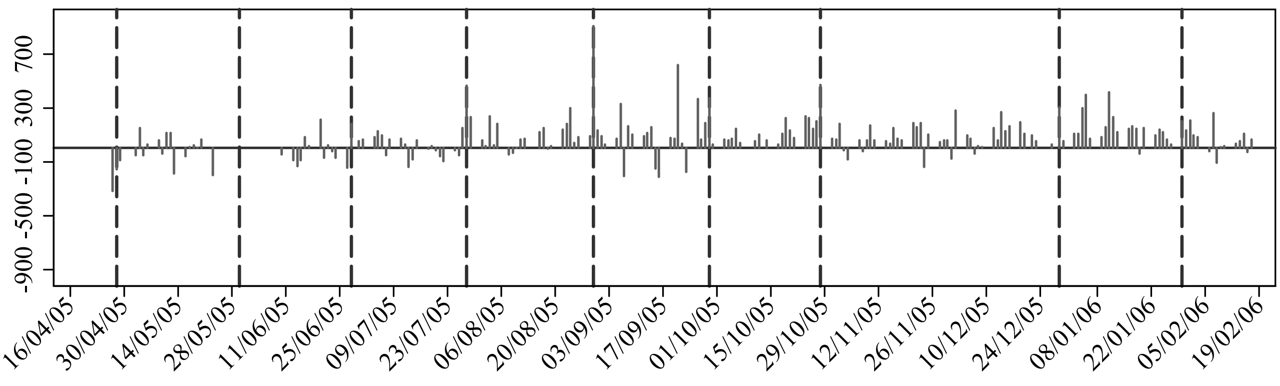
In this section we use the proxies for liquidity to try to understand when a new issued bond acquires the status of benchmark.

7.1 Benchmark analysis

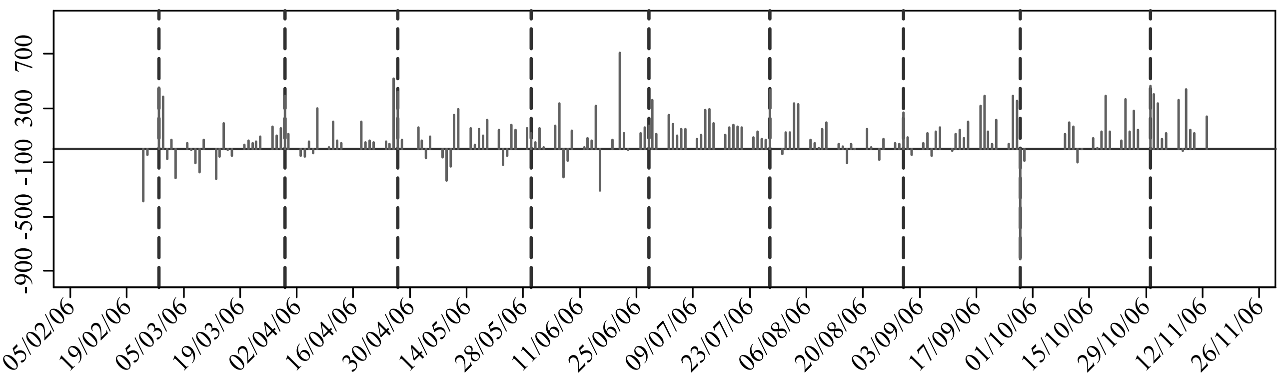
Both in the literature and in the financial industry the concept of benchmark security has been defined in many different ways: "Benchmark means the most liquid security, which is therefore most capable of providing a reference point for the market"; equivalently, "benchmark are issues whose yield are widely followed as macroeconomic indicators and used for pricing related securities" (CGFS, 1999); furthermore, benchmark "is the most recently issued security with a cumulative issue size over a certain threshold" (D'Souza et al., 2003). Other definitions state that "to define benchmark status one should focus directly on price discovery and regard the price discovery process as a purely empirical matter" (Dunne et al., 2002) or "a new bond becomes the benchmark issue when it has been traded more than the old benchmark for at least three consecutive days" (Alonso et al., 2004). Among the definitions adopted in the financial industry we have: "The eligible bond universe, to the status of benchmark, includes bonds issued within the previous two years with principal amount outstanding of € 5 billion at the date of the latest "tap" or auction. Issues of an outstanding volume of € 3 billion may be listed if the issuer commits to tap it to € 5 billion within 180 days of the auction and supported by at least 8 System Participants" (EuroMTS web site); or "also called on-the-run or current-coupon issue or bellwether issue, […] the benchmark issue is the most recently auctioned Treasury issues for each maturity" (Bloomberg web site).

The definition we are going to partially exploit in this analysis is the Alonso et al. (2004) one. In particular, we define as *benchmark a new issue that has been traded more than the old one for at least five consecutive days*. The day in which the security gains the status of benchmark is set equal to the first day of the series. This criterion is fairly general in that we do not assume a specific threshold on the size of the outstanding security. Hence we can compare directly different securities with a simple criterion. Moreover, it is more restrictive with respect to the Alonso et al. (2004) one because it requires a working week and not three days of higher trading volume for the new issue. In the following table we compare our definition with the EuroMTS one. In particular, the latter, in the Italian case, implies that a bond become benchmark as soon as it is issued. According to our definition a bond usually does not acquire the benchmark status as it is issued, but only with a certain delay. Figure 7.1 reports the difference in trading volume between on-the-run and off-the-run 10-year BTPs. The dashed vertical lines correspond to auction days. While in the upper panel the difference seems to be persistently positive after the third auction, in the lower panel this holds before the second auction takes place.

Figure 7.1 Trading volume differences



10Y 08/15 - 10Y 02/15



10Y 08/16 - 10Y 08/15

Note: The figure represents daily differences in the daily trading volume for the 10 year BTPs with maturity 02/15, 08/15 and 08/16. The differences are computed subtracting the trading volume of the off-the-run securities to the trading volume of the on-the-run securities. The differences are computed in millions of euros.

Table 7.1 shows the average number of trading days and the corresponding number of auctions needed for an on-the-run issue to become the benchmark for its segment according to our criterion. The index linked bond is excluded from our analysis because of the high number of days in which the bond is not traded. Referring to the central part of the table, the average difference of days is increasing in the original maturity of the bond and is in general less than 30 working days. If we work out the difference not in terms of days but of number of auctions and consequently of outstanding quantity, this difference is in general less than one auction. This means that the

Table 7.1 – Benchmark analysis

		4 days				*5 days*				*6 days*				
Security	**ISIN code**	**Diff. (days)**	**mean day diff.**	**Num. auctions**	**Average outst.**	**Diff. (days)**	**mean day diff.**	**Num. auctions**	**Average outst.**	**Diff. (days)**	**mean day diff.**	**Num. auctions**	**Average outst.**	**note**
BTP 30	393465	5		1		5		1		132		3		
BTP 10	361838	12		1		12		1		20*		1		idem 6 - 11
	371991	36	22	2	5125	36	33	2	6437.5	72*	51	3	7625	
	384453	19	(10.1)	1	(1315)	63	(22.32)	3	(2164)	90*	(35.7)	4	(3479)	idem 6 - 7
	401958	21		1		21		1		21		1		idem 6 - 11
BTP 5	379959	7		1		7		1		7		1		
	387292	23	13	1	4375	23	27	1	5207.75	23	36	1	6832.75	
	402629	23	(12.39)	1	(750)	23	(19.21)	1	(1180)	59*	(24.68)	3	(3325)	idem 6 - 10
	411281	-2		0		53		2		53		2		idem 6 - 7
BTP 3	367423	11		1		11		1		94*		4		idem 6 - 7
	380485	0		1		0		1		0		1		idem 6 - 10
	387770	28	7	1	4200	35	14	2	4974	35	31	2	6314	
	400812	-3	(12.79)	0	(447)	-3	(17.02)	0	(1226)	-3	(39.07)	0	(3251)	idem 6 - 10
	408524	0		1		29		1		29		1		idem 6 - 9
CTZ	369706	16		1		16		1		16		1		idem 6 - 10
	383119	0	4	1	3250	0	8	1	3250	0	8	1	3250	idem 6 - 7
	392699	0	(8)	1	(500)	0	(8.96)	1	(500)	0	(8.96)	1	(500)	
	405105	0		1		15		1		15		1		

Note: Columns 3-7-11 report the difference in number of trading day between our criterion and the EuroMTS one. Columns 4-8-12 report for each maturity segment the averages of columns 3-7-11. Columns 5-9-13 report the difference in number of auctions, where 0 indicates the when-issue time period. Columns 6-10-14 report for each maturity segment the average outstanding in millions of euros. The last column reports a robustness check for the 6 days criterion. The* indicates that Difference (days) is influenced by the presence of a single day that is missing or of higher trading volume for the off-the-run security. Standard deviations are between brackets.

benchmark status is not acquired immediately, but usually we do not need to wait the first reopening, i.e. the second auction.

This evidence for the Italian securities seems to suggest that the issue sizes are well suited. Conversely, since in many cases the benchmark status is achieved just a few days before the second auction, it may be the case that the expectation of a new issue has a positive impact on trades. Columns 6-10 and 14 report for each segment the average outstanding. This is increasing in the maturity. In order to check the robustness of the “5 days” criterion, the table also displays the number of consecutive days with higher trading volume for the on-the-run securities using different criteria. In particular, we investigate “4 days” and “6 days” criteria. It turns out that tightening the criterion, i.e. increasing the number of days, delays the moment in which the security become benchmark. The number of auctions and the average outstanding increase also. The 10-year BTPs seem to be more sensible to variations in the criterion. However, for this security in 3 cases out of 4 the change from “5 days” to “6 days” criterion is affected by the presence of a single day of lower trading volume for the on-the-run issue with respect to the off-the-run. If we narrow the criterion further, in general we find no significant differences with the “6 days” criterion. The latter result confirms ex post the goodness of the choice of the “5 days” criterion.

7.2 The quote measures’ puzzle

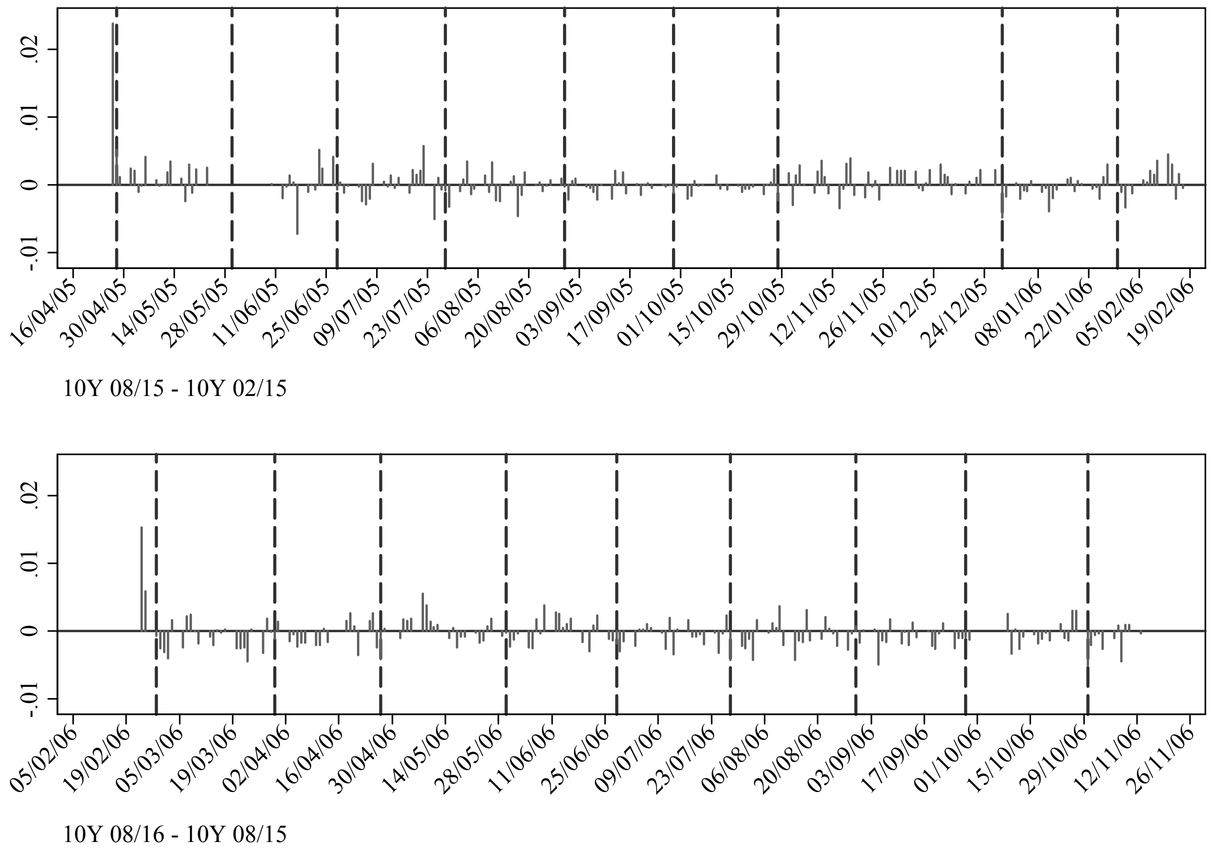
Given the results of the benchmark analysis we ask ourselves if we can extend this way of proceeding to variables other than the trading volume. To this aim, we compare panels A and B of Tables 6.1 and 6.2. As expected, trading measures show a sharp difference between on-the-run and off-the-run securities[84]. In particular trading volume, trading frequency and the turnover ratio for the on-the-run securities are on average twice as big as the off-the-run ones[85]. Furthermore, in the case of off-the-run securities, trading volume and trading frequency are not only smaller, but they are also more volatile. The only trading measure which shows similar values is trade size. Trade size is, on average, about 6-7 millions of euros for 10-year BTPs, and it is slightly larger on the off-the-run securities. These results indicate that other trading variables could be helpful in the evaluation of when an on-the-run security becomes the benchmark reference for its maturity segment.

Given the higher trading activity recorded in the case of the on-the-run securities, a more liquid order book could be expected for those securities[86]. Indeed, we could expect that off-the-run securities trade at a higher spread and a lower depth, whatever measured, with respect to the new

[84] As specified above, for each securities our data comprise both the on-the-run and the first off-the-run periods, and the first six months of the second off-the-run period.
[85] This holds across all the securities in the sample but the index linked BTPs.
[86] Fleming (2003) gives evidence of tighter spreads on on-the-run U.S. Treasury notes.

issues. Hence we should be able to identify when an on-the-run security achieves the status of benchmark in a consistent way with our previous analysis on trading data. Surprisingly, all the order book measures do not show any significant difference between on-the-run and off-the-run securities, Table 6.1. Spread measures have the same average values. Size measures are often even better in the case of off-the-run bonds than in the case of on-the-run bonds[87]. For instance, Figure 7.2 reports the differences in the best spread by analogy with the previous figure. The pattern in the differences is erratic and, especially in the upper panel, the differences are often close to zero.

Figure 7.2 Best spread differences



Note: The figure plots daily differences in the best spread for the 10 year BTPs with maturity 02/15, 08/15 and 08/16. The differences are computed subtracting the best spread of the off-the-run securities to the best spread of the on-the-run securities. Best spreads are daily mean and they are computed in terms of prices.

A reasonable explanation of this evidence has to be looked for in the obligations imposed on market makers on the MTS platform. These obligations are independent on the on-the-run or off-

[87] Data on the other securities in the sample mostly confirm the same evidence. Same evidence is conveyed by data on the hours of trade concentration and on the rest of the day. Only in the case of the 30-year BTPs almost all the liquidity indicators are better in the case of the on-the-run security.

the-run status of the securities[88]. Furthermore, Specialists are monitored by the Italian Treasury and they compete both on the on-the-run and the off-the-run segments of the market in order to reach a good ranking. In effect, Tables 6.1 shows that the number of dealers on the markets is, on average, the same on the on-the-run and on the off-the-run securities. Apparently, MTS and Italian Treasury do not take into account that market makers bear higher costs in the off-the-run segment than in the on-the-run one. As a consequence, the number of market makers in the off-the-run segment is probably higher than it would have been in the absence of obligations and monitoring, and this keeps down off-the-run spreads. This is consistent with our previous findings. In effect, at high frequency level, at a weekly level and in the comparative analysis we always found that order book data show small differences between on-the-run and off-the-run securities.

8. Conclusions

The concept of market liquidity can hardly be pinned down. Actually, it has multidimensional aspects and, consequently, many different measures of markets liquidity are available. We provide a detailed survey of liquidity measures, and according to a taxonomy we discuss their relationship with liquidity. Moreover, we propose four new measures: weighted depth, slope, DS and DSS.

The framework of our analysis is the major wholesale electronic market for Italian Government securities, namely MTS Italy, that for the period under examination accounts for 95% of the transactions in Italian electronic trading venues. MTS markets are an example of quote-driven electronic order book markets. The quality of the order book is particularly relevant. For that reason, our main focus is on order book. We are able to provide an accurate measure of liquidity due to the availability of high frequency data on the whole order book.

Having compared the performance of a large set of liquidity indicators, we indicate those that give a comprehensive description of the most important features of order book and trading data. Among tightness measures, *best spread* is our preferred indicator. It directly quantifies the cost of most of the transactions on the market, it behaves consistently with the other liquidity indicators and it is the most easily available liquidity indicator. *Steepness*, which is the main indicators of breadth, is crucial to understand how the MTS order book moves during the day and reacts to market conditions. The peculiar behaviour of steepness helps us to figure out why best spread, spread and weighted spread often move in opposite directions. However, steepness is not consistent with the other measures of liquidity. It rises when the market seems to be more liquid. As to the depth of the

[88] This is true because all the securities under examination are included in the "liquid" bucket. In effect, the obligations are different for securities belonging to the "not liquid" bucket.

order book, we have shown that *quote size* does not uniformly spread out on the order book. That is why quote size has to be examined together with indicators of size distribution: *Best size* is the simplest and most easily available. Among multidimensional order book indicators, that is indicators which combine more than one dimension of our taxonomy, *slope*, *market quality index* and *CRT* turn up to be good synthetic indicators of market liquidity. Among them, slope is one of the liquidity measures originally elaborated by us and it combines breadth and depth.

No clear and general relationship emerges between trading and order book measures. Trading measures can be split in two groups: The first group comprises *trading volume*, *trading frequency*, *turnover*. They either show no correlation with order book measures, or are combined with less liquid order book, although they convey crucial information about the working of the market. The second group comprises *trade size* and *price impact coefficients*. They move in the same directions of the other liquidity measures. However, price impact coefficients are not easily computable and are not available on a real-time basis. Interestingly, slope is conceptually close to price impact coefficients, even though the amount of data needed to calculate the latter is much larger than the one needed for the former. As a matter of fact, in our data the empirical values of the two indicators are reciprocally consistent, even though they are not weekly correlated. The comparison of trade size with best size data shows that the quantity available on the order book at the best price is fully exploited by the market. Most of trading could occur at the best price. However, we cannot conclude univocally that the liquidity provided at best prices is enough with respect to the operators trading needs.

The analysis of the correlation between size measures and best spread casts new light on the quality of the order book and on the distribution of quote size. When the market becomes more liquid and quote size increases and best spread shrinks, quote size at the best prices falls, the order book becomes steeper and the additional quantities available for trade are placed at the end of the order book. In the end, the quality of the order book seems to be low: Most of the quote size is off the best quote; when the number of the market makers increases, the newcomers quote prices that are far away from the best prices and make the steepness of the order book to jump. A possible explanation for the reduction of best size is in the regulation. Indeed, the maximum spread is tight because of the Liquidity Pact. This reduces market makers' profits and could imply a lower best size when spreads shrinks and profits are smaller. These features could be also signalling that, despite the presence of a large number of market makers, the degree of competition among them is not very high. Unfortunately, we have not data at market participant level and we are not able to see if there are participants who are persistently in the highest/lowest level of the order book.

From the comparison across securities we have that the medium and long term BTPs represent the most liquid segments. CTZs have a good performance in terms of *best spread*, but they are characterized by a more dispersed order book. The 30-year BTPs show performances that are better than expected with respect to the order book measures. On the other hand, trading activity in this segment is still low and only the index linked bonds exhibit lower figures. This latter segment is, not surprisingly, the worst in terms of most of the employed measures.

Finally, we find that although not as liquid as the US market, MTS is more liquid than the Canadian market.

We exploited the new insights about market liquidity in order to understand when a new issued bond acquires the status of benchmark. The empirical evidence shows that the average number of days needed to gain the benchmark status is increasing in the original maturity of the bond and is in general less than 30 working days. This means that the benchmark status is not acquired immediately, but usually we do not need to wait the first reopening, i.e. the second auction. However, in many cases the benchmark status is actually achieved just a few days before the second auction, and it may be the case that the expectation of a new issue has a positive impact on trade. Some modifications of the issuance policy in order to have a larger outstanding since the first auction could help securities in gaining earlier their benchmark status, especially in case of 10-year BTPs. This part of the analysis relies on trading data. Indeed, trading measures show a sharp difference between on-the-run and off-the-run securities. Given the higher trading activity recorded in the case of the on-the-run securities, a more liquid order book could be expected for those securities. Surprisingly, all the order book measures do not show any significant difference between on-the-run and off-the-run securities. A reasonable explanation of this evidence has to be looked for in the obligations imposed on market makers on the MTS platform and on the monitoring procedures of Specialists by Treasury. As a consequence, the number of market makers in the off-the-run segment is higher than it would have been in the absence of obligations and monitoring, and this keeps down off-the-run spreads. Overall, our analysis points out to an important role of market microstructure in affecting liquidity.

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Appendix A: Data Filtering

The raw dataset has to be filtered for two reasons: the presence of both negative bid-ask best spreads and outliers. Those drawbacks can be the consequence of some technical inconveniences in the procedure of data transfer from MTS to Italian Treasury. In the period 2004-2005 the number of records transferred to the Treasury is occasionally and marginally different with respect to the number of records in MTS data base. This generates cases of negative bid-ask spreads, which are inconsistent with the working of MTS platform. In effect, on MTS platform an ask proposal with a price smaller than the price of a bid proposal would be automatically executed. The same technical inconvenience could generate false outliers among the proposals. For false outlier we mean that bid (ask) quotes may seem to be too low (high) with respect to the other quotes in the same snapshot just because some records in between are missing. However, outliers could be the outcome of the behaviour of market makers as well.

First our filtering procedure eliminates all the snapshots where a negative best spread is present. Secondly, outliers are filtered out using thresholds on the gaps between prices within the same snapshot. For instance if the gap between the best bid price and the second best price is above the fixed threshold, this price and all the subsequent prices are filtered out. The thresholds are chosen in a way that they cut the sample around the 95% percentile. However, especially during the hours characterized by a lower trading activity, i.e. before 9.00am, after 4.00pm and around 1.00pm, the sample includes snapshots with only one bid and ask proposal. We call these “unique proposals”. Obviously we cannot apply the gap threshold in this case; hence we set a second threshold which is equal to the maximum spread we observe in the other snapshots. The maximum spread is the difference between the higher ask price and the lower bid price. The days characterized by problems in the working of the platform and by the suspension of the market making obligations are also excluded from the sample. The day the Citigroup-episode happened, i.e. August 2nd 2004, along with the day preceding and following that date are excluded from the sample as well. Tables A.1 and A.2 report respectively the effects of the filtering procedure on the original sample and the thresholds. The filtering procedure is worked out security by security.

Table A.1 Filtering procedure’s output

quotes	Obligations' suspension	Bestspread < 0	Gaps	Unique quotes	Other	total
BTP 30	1.13	0.004	2.81	0.04	0	3.99
BTP 10	0.51	0.16	5.19	0.02	0.005	5.89
BTP 5	1.28	0.06	4.85	0.01	0	6.20
BTP 3	0.80	0.04	3.58	0.01	0.18	4.61
BTP 10 ind	1.61	0.01	3.84	0.01	0.00	5.50
CTZ	0.74	0.10	2.33	0.02	0.00	3.19

contracts	Obligations' suspension	total
BTP 30	0.71	0.71
BTP 10	0.51	0.51
BTP 5	0.79	0.79
BTP 3	0.70	0.70
BTP 10 ind	4.14	4.14
CTZ	0.86	0.86

Note: The figures in the table are percentage. The breakdown of the sample is in Table 5.1.

Table A.2 Thresholds

	Gap	Max Spread
BTP 30	0.04	0.4
BTP 10	0.02	0.28
BTP 5	0.02	0.23
BTP 3	0.02	0.17
BTP10ind	0.06	0.42
CTZ	0.01	0.06

Note: The thresholds are measured in ticks.

Appendix B: Formulae

The signed variables represent mean values with respect to the *i*-th snapshot. For the sake of simplicity, the index *i* is usually ignored. $ask(bid)price_k$ is the *k*-th best quote on the ask(bid) side of the book. The number of proposals on the ask(bid) side of the book in the *i*-th snapshot are $n_{ask(bid)}$. Therefore, k = 1, 2, ..., $n_{ask(bid)}$. $ask(bid)qty_k$ is the quantity associated to the *k*-th best quote on the ask(bid) side of the book. The cumulative quantity from the first to the *k*-th position on the ask(bid) side of the book is given by $ask(bid)qtycumul_k \equiv \sum_{j=1}^{k} ask(bid)qty_j$. We divide the measures in two cathegories: Measures from quoting data and measures from trading data.

Measures from quoting data

- $best\ spread \equiv bestaskprice - bestbidprice$,
  where $bestask(bid)price \equiv ask(bid)price_1$;
- $spread \equiv \overline{askprice} - \overline{bidprice}$,
  where the bar indicates the average of the variable and the average is on all the quotes on the corresponding side of the book;
- $weighted\ spread \equiv \sum_{i=1}^{n_{ask}} askprice_i \cdot askweight_i - \sum_{i=1}^{n_{bid}} bidprice_i \cdot bidweight_i$,
  where the weights are $ask(bid)weight_i \equiv \dfrac{ask(bid)qty_i}{ask(bid)qtycumul_{n_{ask(bid)}}}$;
- $quote\ size \equiv \dfrac{bidquotesize + askquotesize}{2}$,
  where $ask(bid)quotesize \equiv ask(bid)qtycumul_{n_{ask(bid)}}$;
- $best\ size \equiv \dfrac{bidbestsize + askbestsize}{2}$,
  where $ask(bid)bestsize \equiv ask(bid)qty_1$;
- $second\ size \equiv \dfrac{bidscndsize + asksconsize}{2}$,
  where $ask(bid)sndsize \equiv ask(bid)qty_2$;

- $worst\ size \equiv \dfrac{bidworstsize + askworstsize}{2}$,

  where $ask(bid)worstsize \equiv \sum_{j=3}^{n_{ask(bid)}} ask(bid)qty_j$;

- $average\ quote\ size \equiv \dfrac{\overline{askquotesize} + \overline{bidquotesize}}{2}$,

  where $\overline{ask(bid)quotesize} \equiv \dfrac{ask(bid)quotesize}{n_{ask(bid)}}$;

- $weighted\ depth \equiv \dfrac{bidwghtdepth + askwhgdepth}{2}$,

  where $bid(ask)wghtdepth \equiv \sum_{k=1}^{n_{bid(ask)}} \dfrac{bid(ask)qty_k}{1 + \left|\left(bestbid(ask)price - bid(ask)price_k\right)\right| * 100}$;

- $quote\ size\ per\ market\ participant \equiv \dfrac{quotesize}{marketparticipants}$,

  where *marketparticipants* measures the number of market makers who expose a double quote in each snapshot;

- $steepness \equiv \dfrac{bidsteepness + asksteepness}{2}$,

  where $bid(ask)steepness \equiv \dfrac{\left|bestbid(ask)price - worstbid(ask)price\right| * 100}{\dfrac{bestbid(ask)price + worstbid(ask)price}{2}}$;

- $slope \equiv \dfrac{bidslope + askslope}{2}$,

  where $bid(ask)slope \equiv \dfrac{\left|bestbid(ask)price - worstbid(ask)price\right| * 100}{bid(ask)quotesize - bid(ask)bestsize}$;

- $DS \equiv \dfrac{DBS + DAS}{2}$,

  where $DBS\ (DAS) \equiv \dfrac{\mathrm{cov}\left(bid(ask)price_k, bid(ask)qtycumul_k\right)}{\mathrm{var}(bid(ask)qtycumul_k)}$

- $Deepspread_l = askprice_{k_l^{ask}} - bidprice_{k_l^{bid}}$ for l = 2.5, 5, 7.5, 10, …

  where $k_l^{ask(bid)} = \min\left\{k \middle| \ ask(bid)qtycum_k \geq l\right\}$

- $DSS \equiv \dfrac{\mathrm{cov}\left(deepspread_m, m\right)}{\mathrm{var}(m)}$,

  where m is a multiple of 2.5 and indicates the cumulative quantities at which $deepspread_m \neq deepspread_{m\text{-}1}$;

- $market\ quality\ index = \dfrac{averagequotesize * midquote}{spread * 10000}$,

  where $midquote = \dfrac{\left(\overline{askprice_i} + \overline{bidprice_i}\right)}{2}$;

- $market\ quality\ index\ 2 = \dfrac{quotesize * midquote}{spread * 10000}$;

- $$CRT(L) = \frac{2\left(\sum_{k=1}^{n_{ask}} I_k^{ask}\, askprice_k \cdot askqty_k - \sum_{k=1}^{n_{bid}} I_k^{bid}\, bidprice_k \cdot bidqty_k\right)}{L(bestaskprice + bestbidprice)},$$

  where

  $$I_k^{ask(bid)} = \begin{cases} 1 & \text{if} \quad L > ask(bid)qtycumul_k \\ \frac{L - ask(bid)qtycumul_{k-1}}{ask(bid)qty_k} & \text{if} \quad ask(bid)qtycumul_{k-1} < L < ask(bid)qtycumul_k \\ 0 & \text{if} \quad \text{otherwise} \end{cases}$$

- *absolute price change* = $\left|midquote_i - midquote_{i-1}\right|$.

Measures from trading data

- *trading volume* = $\frac{(tradesize * contractprice)}{100}$
- *trading frequency* = #contracts concluded in the time interval
- *turnover ratio* = $\frac{tradingvolume}{outstanding}$
- *net trading count* = *(#buy contracts − #sell contracts)*
- *net trading quantity* = $volumebuy - volumesell$

Appendix C: Tables

Table C.1 – Summary Statistics BTP 30 (5 min freq)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
best spread	0.104	0.029	0.090	0.100	0.120	0	0.400
spread	0.171	0.018	0.163	0.171	0.180	0.010	0.400
weighted spread	0.169	0.016	0.163	0.169	0.176	0.010	0.400
best size	7.53	3.70	5	6.3	9	2.5	38
second size	12.06	6.49	8	11.3	16.3	2.50	63
worst size	67.07	31.90	46.3	75	91	0	144
quote size	83.08	37.62	55.0	95	113	3	173
average quote size	11.64	3.78	9.0	12	14	2.50	26.3
weighted depth	26.27	10.80	18.79	27.42	33.89	3	69.5
qte size per partic.	7.60	1.07	7.13	7.69	8.24	3	13.3
steepness	0.07	0.02	0.06	0.07	0.08	0.01	0.17
slope	0.12	0.11	0.07	0.09	0.12	0.03	1.6
DS	13.48	8.84	8.40	10.77	14.82	3.04	79.13
DSS	0.0021	0.0024	0.0011	0.0014	0.0020	0.0005	0.066
mkt quality index	0.70	0.23	0.54	0.73	0.86	0.06	5.87
CRT 10	0.11	0.03	0.09	0.11	0.13	0.02	0.36
abs price change	0.032	0.032	0.01	0.022	0.043	0	0.541
mkt participants	10.69	4.67	7.36	12.07	14.25	1	21.17
Panel B: off-the-run							
best spread	0.110	0.026	0.090	0.110	0.120	0	0.40
spread	0.173	0.015	0.166	0.174	0.181	0.030	0.40
weighted spread	0.170	0.013	0.165	0.171	0.176	0.027	0.40
best size	7.30	3.57	5	6.3	9	2.5	68
second size	11.51	6.58	6	10.0	15.0	2.50	71
worst size	58.21	27.97	40.0	65	79	0	181
quote size	74.09	33.38	50.0	83	100	3	203
average quote size	10.79	3.61	8.2	11	13	2.50	24.4
weighted depth	24.57	10.18	17.79	25.27	31.43	3	91.5
qte size per partic.	6.82	0.95	6.29	6.87	7.42	3	15.6
steepness	0.06	0.02	0.05	0.06	0.07	0.01	0.14
slope	0.14	0.12	0.08	0.10	0.14	0.04	1.6
DS	17.25	11.38	10.48	13.75	19.16	2.97	89.82
DSS	0.0022	0.0021	0.0012	0.0015	0.0021	0.0003	0.052
mkt quality index	0.74	0.23	0.57	0.76	0.90	0.07	2.18
CRT 10	0.10	0.02	0.09	0.10	0.11	0.03	0.28
abs price change	0.034	0.034	0.01117	0.02	0.05	0	0.564
mkt participants	10.68	4.60	7.47	12.15	14.10	1	21.21

Table C.2 – Summary Statistics BTP 5 (5 min freq)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
best spread	0.022	0.008	0.020	0.020	0.020	0	0.23
spread	0.042	0.007	0.040	0.040	0.045	0.005	0.23
weighted spread	0.039	0.005	0.036	0.038	0.041	0.007	0.23
best size	43.26	25.90	23	40.0	60	2.5	195
second size	85.63	38.96	58	88.8	115.0	2.50	213
worst size	26.34	22.69	10.0	20	36	0	143
quote size	152.32	60.07	110.0	168	200	3	285
average quote size	50.88	20.25	36.7	52	65	2.50	133.8
weighted depth	93.28	37.34	66.88	97.50	120.83	3	232.9
qte size per partic.	8.87	2.00	7.50	8.33	10.34	2	30.0
steepness	0.02	0.01	0.02	0.02	0.02	0.01	0.05
slope	0.03	0.03	0.01	0.02	0.03	0.01	0.6
DS	3.04	3.25	1.42	1.89	3.05	0.64	46.36
DSS	0.0003	0.0004	0.0002	0.0002	0.0004	0.0001	0.015
mkt quality index	12.46	5.61	8.40	12.00	16.10	0.26	48.02
CRT 10	0.02	0.01	0.02	0.02	0.03	0.00	0.23
abs price change	0.009	0.010	0.003	0.008	0.013	0	0.24
mkt participants	17.83	7.51	12	19	24	1	31
Panel B: off-the-run							
best spread	0.021	0.007	0.020	0.020	0.020	0	0.210
spread	0.038	0.006	0.035	0.040	0.040	0.020	0.210
weighted spread	0.036	0.004	0.034	0.036	0.038	0.020	0.210
best size	47.96	28.42	25	47.5	65	2.5	213
second size	92.95	41.23	60	100.0	122.5	2.50	233
worst size	20.51	20.55	5.0	15	28	0	143
quote size	158.16	61.74	115.0	178	200	4	300
average quote size	57.72	22.24	43.1	60	73	2.50	145.0
weighted depth	99.34	39.64	72.50	105.83	126.67	0	236.3
qte size per partic.	9.64	1.88	8.24	9.13	11.03	2	38.3
steepness	0.02	0.00	0.01	0.02	0.02	0.01	0.05
slope	0.02	0.03	0.01	0.02	0.02	0.00	0.5
DS	2.92	3.21	1.30	1.68	2.97	0.54	53.28
DSS	0.0003	0.0004	0.0001	0.0002	0.0003	0.0000	0.030
mkt quality index	15.36	6.36	11.00	15.60	19.57	0.24	46.69
CRT 10	0.02	0.01	0.02	0.02	0.02	0.00	0.15
abs price change	0.007	0.008	0.0025	0.01	0.01	0	0.165
mkt participants	16.98	7.41	11.67	17.17	24	1	31

Table C.3 – Summary Statistics BTP 3 (5 min freq)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
best spread	0.017	0.007	0.010	0.020	0.020	0	0.170
spread	0.034	0.006	0.030	0.035	0.035	0.005	0.170
weighted spread	0.033	0.004	0.031	0.032	0.034	0.005	0.173
best size	50.79	31.30	25	42.5	75	2.5	195
second size	95.70	42.68	65	100.0	125.0	2.50	233
worst size	18.74	18.31	5.0	13	30	0	118
quote size	162.37	62.91	117.5	180	210	3	308
average quote size	60.75	24.13	43.8	63	78	2.50	140.0
weighted depth	103.43	41.23	74.58	108.33	132.79	3	228.8
qte size per partic.	11.79	1.61	10.83	11.72	12.68	3	51.3
steepness	0.02	0.01	0.01	0.02	0.02	0.01	0.05
slope	0.02	0.03	0.01	0.02	0.02	0.005	0.6
DS	2.99	3.32	1.25	1.72	3.13	0.55	53.71
DSS	0.0003	0.0005	0.0001	0.0002	0.0003	0	0.022
mkt quality index	18.18	8.01	12.34	18.14	23.62	0.19	60
CRT 10	0.02	0.01	0.01	0.02	0.02	0.00	0.16
abs price change	0.004	0.006	0	0.003	0.008	0	0.14
mkt participants	13.83	5.33	10	15.40	17.8333	1	25
Panel B: off-the-run							
best spread	0.016	0.006	0.010	0.020	0.020	0	0.160
spread	0.033	0.004	0.030	0.030	0.035	0.015	0.160
weighted spread	0.031	0.003	0.030	0.031	0.032	0.012	0.160
best size	57.81	35.18	28	47.5	88	5.0	228
second size	102.64	44.69	73	105.0	132.5	5.00	280
worst size	15.32	16.75	2.5	10	25	0	113
quote size	172.90	64.46	130.0	193	220	5	320
average quote size	68.12	26.31	50.8	69	86	5.00	165.0
weighted depth	112.82	43.67	83.75	117.50	144.17	5	245.0
qte size per partic.	12.33	1.43	11.36	12.22	13.16	5	26.4
steepness	0.02	0.00	0.01	0.02	0.02	0.01	0.04
slope	0.02	0.02	0.01	0.01	0.02	0.00	0.3
DS	2.85	3.13	1.14	1.59	3.06	0.46	28.66
DSS	0.0002	0.0002	0.0001	0.0001	0.0002	0.0000	0.007
mkt quality index	21.27	8.80	15.17	21.62	26.42	0.45	64.96
CRT 10	0.02	0.01	0.01	0.02	0.02	0.00	0.16
abs price change	0.004	0.005	0	0.00	0.01	0	0.110
mkt participants	14.13	5.35	10.5	15.67	18.13	1	25.83

Table C.4 – Summary Statistics CTZ (5 min freq)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
best spread	0.007	0.004	0.004	0.006	0.008	0	0.059
spread	0.019	0.004	0.017	0.019	0.021	0.002	0.059
weighted spread	0.018	0.004	0.015	0.017	0.019	0.002	0.059
best size	9.70	6.81	5	7.5	13	2.5	113
second size	11.47	7.42	6	10.0	15.0	2.50	78
worst size	90.44	38.07	66.3	96	118	0	206
quote size	110.31	41.97	83.8	118	141	3	251
average quote size	10.36	2.61	8.7	10	12	2.50	48.8
weighted depth	75.48	28.45	57.48	79.34	96.72	3	191.7
qte size per partic.	9.21	1.90	8.09	9.01	10.08	3	37.5
steepness	0.02	0.00	0.01	0.02	0.02	0.00	0.03
slope	0.02	0.02	0.01	0.02	0.02	0.004	0.4
DS	10.52	5.31	7.29	9.16	12.21	2.48	65.82
DSS	0.0003	0.0003	0.0002	0.0002	0.0003	0	0.008
mkt quality index	5.36	1.93	4.02	5.25	6.46	0.40	48
mkt qual index 2	55.65	22.38	40.76	57.37	71.83	0.40	153
CRT 10	0.01	0.00	0.01	0.01	0.01	0.00	0.06
abs price change	0.002	0.003	0.0005	0.001	0.003	0	0.08
mkt participants	12.18	4.66	9	13.56	15.72	1	23
Panel B: off-the-run							
best spread	0.005	0.003	0.003	0.004	0.006	0	0.052
spread	0.016	0.003	0.014	0.016	0.019	0.004	0.054
weighted spread	0.013	0.003	0.011	0.013	0.016	0.004	0.054
best size	11.35	12.14	6	8.8	14	2.5	503
second size	14.37	10.80	8	12.5	18.8	2.50	511
worst size	84.41	36.18	62.5	91	106	0	595
quote size	109.16	42.48	85.0	118	134	3	623
average quote size	11.09	3.96	9.2	11	13	2.50	174.5
weighted depth	80.29	32.21	62.18	83.42	97.77	3	518.6
qte size per partic.	8.49	2.87	7.35	8.13	9.06	3	215.1
steepness	0.01	0.00	0.01	0.01	0.02	0.001	0.03
slope	0.02	0.01	0.01	0.01	0.02	0.003	0.4
DS	9.99	5.45	6.65	8.89	11.90	1.15	69.43
DSS	0.0002	0.0002	0.0002	0.0002	0.0002	0	0.007
mkt quality index	6.99	3.56	5.00	6.30	8.24	0.58	190.36
mkt qual index 2	66.31	28.48	51.00	65.92	81.28	0.60	571.09
CRT 10	0.01	0.00	0.00	0.01	0.01	0.001	0.04
abs price change	0.001	0.002	0.00025	0.00	0.00	0	0.044
mkt participants	13.17	4.88	9.75	14.83	16.77	1	23.58

Table C.5 – Summary Statistics BTP 10ind (5 min freq)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
best spread	0.105	0.032	0.080	0.100	0.120	0	0.33
spread	0.198	0.021	0.189	0.201	0.211	0.03	0.352
weighted spread	0.201	0.019	0.194	0.204	0.212	0.03	0.352
best size	10.70	4.55	8	10.0	13	2.5	50
second size	13.44	6.53	9	12.5	17.5	2.50	65
worst size	103.48	41.99	76.3	114	135	0	196
quote size	125.80	44.65	97.5	138	160	3	213
average quote size	15.27	3.31	13.2	15	17	2.50	30.0
weighted depth	32.94	10.17	26.42	33.28	39.67	3	86.4
qte size per partic.	14.45	1.91	13.49	14.52	15.58	3	23.1
steepness	0.09	0.02	0.08	0.09	0.11	0.01	0.19
slope	0.11	0.10	0.07	0.08	0.11	0.034	2.4
DS	10.15	4.81	7.34	8.98	11.42	2.44	75.50
DSS	0.0017	0.0012	0.0011	0.0014	0.0018	0	0.027
mkt quality index	0.81	0.18	0.70	0.81	0.92	0.08	3
CRT 10	0.11	0.03	0.09	0.10	0.12	0.01	0.26
abs price change	0.017	0.018	0.005	0.012	0.023	0	0.42
mkt participants	8.65	2.97	7	9.47	10.90	1	17
Panel B: off-the-run							
best spread	0.084	0.028	0.070	0.080	0.10	0	0.250
spread	0.179	0.017	0.171	0.180	0.189	0.050	0.290
weighted spread	0.180	0.015	0.174	0.181	0.188	0.055	0.277
best size	11.76	5.34	8	10.0	15	2.5	44
second size	16.28	8.01	10	15.0	20.0	2.50	61
worst size	115.32	45.21	85.0	126	151	0	198
quote size	141.55	49.05	110.0	156	180	3	220
average quote size	16.14	3.40	14.2	16	18	2.50	28.0
weighted depth	37.91	12.02	30.37	38.53	45.73	3	84.7
qte size per partic.	14.42	1.86	13.42	14.54	15.57	3	20.0
steepness	0.10	0.02	0.09	0.10	0.11	0.01	0.16
slope	0.09	0.08	0.06	0.07	0.10	0.04	1.6
DS	9.87	4.42	7.33	8.79	11.01	3.41	60.99
DSS	0.0017	0.0012	0.0011	0.0013	0.0017	0.0007	0.019
mkt quality index	0.93	0.19	0.82	0.94	1.05	0.13	2.07
CRT 10	0.09	0.02	0.07	0.09	0.10	0.02	0.26
abs price change	0.013	0.014	0.00375	0.01	0.02	0	0.323
mkt participants	9.76	3.32	7.44	10.79	12.29	1	16.21

Table C.6 – Summary Statistics Trading Measures BTP 30 (daily*)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
trading volume	50.17	52.31	16.03	35.64	65.22	2.27	511.22
trading frequency	13.84	14.60	5	10	17	1	183
turnover	0.38	0.41	0.14	0.26	0.47	0.01	3.53
tradesize	3.51	1.49	3	3	5	1	30
Panel B: off-the-run							
trading volume	30.87	38.96	8.74	18.61	38.81	2.61	461.21
trading frequency	7.32	8.89	2	4	9	1	91
turnover	0.18	0.21	0.05	0.11	0.23	0.01	2.50
tradesize	3.62	1.51	3	3	5	2.5	27.5

Table C.7 – Summary Statistics Trading Measures BTP 5 (daily*)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
trading volume	154.55	118.12	70.56	126.53	209.80	2.56	807.98
trading frequency	26.51	22.20	12	21	34	1	170
turnover	1.59	1.68	0.60	1.15	2.05	0.02	15.85
tradesize	5.86	2.67	5	5	8	1	40
Panel B: off-the-run							
trading volume	75.98	65.71	34.91	61.55	101.34	4.79	974.79
trading frequency	11.46	9.70	5	9	15	1	146
turnover	0.47	0.45	0.21	0.38	0.61	0.03	5.86
tradesize	6.63	2.46	5	5	10	0.5	20

Table C.8 – Summary Statistics Trading Measures BTP 3 (daily*)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
trading volume	201.60	159.09	100.49	164.18	256.79	5.01	1231.94
trading frequency	29.99	22.98	15	25	38	1	193
turnover	2.30	2.69	0.89	1.58	2.78	0.04	27.88
tradesize	6.72	3.26	5	5	10	2.0	75
Panel B: off-the-run							
trading volume	120.43	94.73	53.95	100.15	154.53	4.92	745.48
trading frequency	16.58	12.62	8	13	22	1	87
turnover	0.72	0.57	0.31	0.58	0.91	0.03	4.49
tradesize	7.28	2.71	5	5	10	2.0	55

Table C.9 – Summary Statistics Trading Measures CTZ (daily*)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
trading volume	165.32	144.05	71.31	131.38	207.71	2.39	1306.00
trading frequency	42.86	30.44	21	36.5	55	1	212
turnover	2.27	2.74	0.79	1.50	2.70	0.03	30.12
tradesize	4.06	3.49	3	3	5	0.5	90
Panel B: off-the-run							
trading volume	90.87	76.59	36.72	71.87	125.22	2.40	719.18
trading frequency	23.56	18.56	10	19	32	1	186
turnover	0.69	0.58	0.29	0.55	0.94	0.02	5.89
tradesize	3.98	3.19	3	3	5	0.5	100

Table C.10 – Summary Statistics Trading Measures BTP 10ind (daily*)

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
trading volume	50.66	50.47	16.09	33.36	65.86	2.50	360.40
trading frequency	8.06	8.11	3	5	11	1	55
turnover	0.55	0.73	0.14	0.31	0.66	0.02	4.93
tradesize	6.03	3.30	3	5	10	2.5	40
Panel B: off-the-run							
trading volume	43.48	40.46	15.22	30.92	59.08	2.55	205.15
trading frequency	7.19	6.35	3	5	10	1	32
turnover	0.30	0.28	0.10	0.21	0.41	0.02	1.41
tradesize	5.90	3.07	3	5	10	1	10

* *trade size* is at a contract level, daily figures are included in the attached folders.

Table C.11 - Summary Statistics BTP 30 on-the-run (weekly freq)

	N	mean	sd	p25	p50	p75	min	max
best spread	102	0.104	0.010	0.098	0.105	0.109	0.082	0.143
spread	102	0.171	0.007	0.165	0.172	0.175	0.155	0.192
weighted spread	102	0.169	0.007	0.163	0.169	0.173	0.153	0.190
best size	102	7.54	0.80	7	7.4	8	5.3	10
second size	102	11.93	2.15	10	11.7	13.1	7.11	18
worst size	102	66.18	8.50	62.5	67	71	37	83
quote size	102	82.68	9.95	78.3	84	90	53	98
average quote size	102	11.61	1.20	11.0	12	13	7.83	14.4
weighted depth	102	26.17	3.10	24.37	26.21	28.51	16	33.8
qte size per partic.	102	7.59	0.35	7.39	7.60	7.82	7	8.6
steepness	102	0.07	0.01	0.06	0.07	0.08	0.05	0.09
slope	102	0.12	0.02	0.11	0.12	0.13	0.09	0.2
DS	102	13.91	2.46	11.91	13.73	15.90	9.25	20.50
DSS	102	0.0021	0.0004	0.0018	0.0020	0.0023	0.0016	0.004
mkt quality index	102	0.70	0.09	0.65	0.70	0.76	0.46	0.89
CRT 10	102	0.11	0.02	0.10	0.11	0.12	0.08	0.14
abs price change	102	0.032	0.006	0.028	0.031	0.034	0.019	0.050
mkt participants	102	10.65	1.06	10.07	10.75	11.34	7.07	12.44
trade size	102	3.49	0.34	3.29	3.50	3.75	2.65	4.32
trading volume	102	72.42	55.03	36.80	63.93	91.71	6.24	379.61
trading frequency	102	19.90	16.38	10.06	16.66	24.94	1.67	134.47
turnover ratio	102	0.55	0.44	0.27	0.44	0.61	0.04	2.63
NTQ	101	0.0018	0.0027	0.0005	0.0019	0.0031	-0.0088	0.0110
NTC	101	0.0071	0.0097	0.0024	0.0079	0.0125	-0.0317	0.0397

Table C.12 – Summary Statistics BTP 5 on-the-run (weekly freq)

	N	mean	sd	p25	p50	p75	min	max
best spread	134	0.022	0.003	0.020	0.021	0.023	0.017	0.029
spread	134	0.042	0.004	0.039	0.041	0.044	0.035	0.054
weighted spread	134	0.039	0.004	0.036	0.038	0.041	0.033	0.050
best size	134	42.99	7.66	36	42.9	49	25.3	58
second size	134	84.57	14.07	77	86.1	92.0	36.04	116
worst size	134	26.16	6.09	21.2	25	31	15	40
quote size	134	151.66	20.02	142.1	154	165	80	196
average quote size	134	50.63	9.06	45.4	51	56	26.22	69.8
weighted depth	134	92.81	13.32	84.27	94.43	102.42	49	122.9
qte size per partic.	134	8.84	1.71	7.63	8.33	10.64	6	12.1
steepness	134	0.02	0.002	0.02	0.02	0.02	0.02	0.03
slope	134	0.03	0.01	0.02	0.03	0.03	0.02	0.1
DS	134	3.16	0.60	2.77	3.05	3.55	2.23	6.33
DSS	130	0.0003	0.0001	0.0002	0.0003	0.0003	0.0002	0.001
mkt quality index	134	12.39	3.01	10.00	12.22	14.85	6.04	18.61
CRT 10	134	0.02	0.00	0.02	0.02	0.02	0.02	0.03
abs price change	134	0.009	0.002	0.007	0.008	0.010	0.005	0.017
mkt participants	134	17.81	3.03	14.97	19.25	20.09	8.18	21.89
trade size	129	6.12	0.88	5.81	6.21	6.67	3.25	8.19
trading volume	129	189.44	102.90	99.11	168.84	247.93	36.35	549.97
trading frequency	129	32.33	21.13	17.43	27.93	39.10	5.40	125.95
turnover ratio	125	2.05	1.81	0.88	1.59	2.48	0.22	11.36
NTQ	129	0.0003	0.0004	0.0001	0.0003	0.0005	-0.0011	0.0013
NTC	129	0.0020	0.0024	0.0009	0.0020	0.0031	-0.0083	0.0086

Table C.13 – Summary Statistics BTP 3 on-the-run (weekly freq)

	N	mean	sd	p25	p50	p75	min	max
best spread	153	0.017	0.002	0.016	0.017	0.018	0.014	0.021
spread	153	0.035	0.003	0.033	0.034	0.036	0.028	0.042
weighted spread	153	0.033	0.002	0.031	0.032	0.034	0.026	0.039
best size	153	50.49	9.45	44	52.0	58	20.5	70
second size	153	94.40	13.74	86	96.0	103.8	26.22	121
worst size	153	18.55	4.52	15.4	18	21	8	30
quote size	153	161.61	21.69	149.1	165	178	72	201
average quote size	153	60.45	9.54	54.8	62	67	21.52	83.2
weighted depth	153	102.90	15.21	93.63	106.22	114.40	43	133.2
qte size per partic.	153	11.78	0.72	11.42	11.87	12.22	10	13.7
steepness	153	0.02	0.002	0.02	0.02	0.02	0.01	0.02
slope	153	0.02	0.01	0.02	0.02	0.02	0.02	0.1
DS	153	3.12	0.85	2.61	2.96	3.34	2.15	8.56
DSS	153	0.0003	0.0002	0.0002	0.0002	0.0003	0.0001	0.002
mkt quality index	153	18.08	3.61	15.55	18.67	20.75	5.29	27.16
CRT 10	153	0.02	0.00	0.02	0.02	0.02	0.01	0.02
abs price change	153	0.004	0.001	0.004	0.004	0.005	0.003	0.007
mkt participants	153	13.77	1.42	13.05	14.03	14.80	6.80	16.17
trade size	153	6.78	0.74	6.22	6.84	7.33	4.87	8.60
trading volume	153	258.86	159.40	160.57	219.18	310.54	45.36	1086.43
trading frequency	153	38.26	23.83	23.19	32.60	46.50	6.81	193.00
turnover ratio	153	3.02	3.26	1.38	2.11	3.32	0.40	27.16
NTQ	153	0.0002	0.0001	0.0001	0.0002	0.0002	-0.0003	0.0006
NTC	153	0.0013	0.0010	0.0008	0.0012	0.0019	-0.0023	0.0039

Table C.14 – Summary Statistics CTZ on-the-run (weekly freq)

	N	mean	sd	p25	p50	p75	min	max
best spread	143	0.007	0.003	0.005	0.006	0.008	0.004	0.028
spread	143	0.020	0.003	0.017	0.019	0.021	0.015	0.031
weighted spread	143	0.017	0.003	0.015	0.017	0.019	0.012	0.031
best size	143	9.68	1.86	8	9.5	11	5.7	17
second size	142	11.43	2.58	9	11.0	13.5	6.56	18
worst size	142	89.56	14.02	81.3	91	97	30	122
quote size	143	109.21	18.13	99.7	112	122	10	142
average quote size	143	10.33	1.50	9.3	10	11	6.76	13.9
weighted depth	143	74.23	14.05	66.25	77.19	85.16	7	96.2
qte size per partic.	143	9.20	0.99	8.62	9.10	9.85	7	12.1
steepness	142	0.02	0.002	0.01	0.02	0.02	0.01	0.02
slope	142	0.02	0.01	0.02	0.02	0.02	0.01	0.1
DS	142	10.67	2.20	9.10	10.40	11.44	7.09	17.74
DSS	143	0.0003	0.0002	0.0002	0.0003	0.0003	0.0002	0.002
mkt quality index	143	5.32	1.37	4.29	5.41	6.25	2.44	8.86
mkt qual index 2	143	54.99	13.02	45.95	57.81	64.63	3.44	81.48
CRT 10	143	0.01	0.00	0.01	0.01	0.01	0.01	0.03
abs price change	143	0.002	0.001	0.002	0.002	0.003	0.001	0.004
mkt participants	143	12.07	1.71	11.66	12.23	13.05	1.02	15.07
trade size	142	4.00	0.71	3.51	3.84	4.40	2.81	6.42
trading volume	142	212.10	125.98	126.22	176.85	272.91	23.91	792.28
trading frequency	142	53.12	25.77	35.04	47.15	67.06	8.00	133.25
turnover ratio	142	2.93	2.67	1.36	2.23	3.46	0.42	18.22
NTQ	142	0.0001	0.0001	0.0000	0.0001	0.0002	-0.0003	0.0006
NTC	142	0.0006	0.0005	0.0003	0.0006	0.0009	-0.0010	0.0023

Table C.15 – Summary Statistics BTP 10ind on-the-run (weekly freq)

	N	mean	sd	p25	p50	p75	min	max
best spread	102	0.105	0.014	0.095	0.105	0.114	0.077	0.144
spread	102	0.198	0.009	0.191	0.2	0.205	0.178	0.216
weighted spread	102	0.201	0.009	0.194	0.202	0.208	0.183	0.221
best size	102	10.74	1.19	10	10.6	11	8.6	15
second size	102	13.42	1.49	12	13.4	14.4	10.38	18
worst size	102	102.69	10.61	97.9	103	109	45	126
quote size	102	125.50	11.09	120.5	127	133	63	152
average quote size	102	15.24	0.95	14.7	15	16	11.37	17.9
weighted depth	102	32.92	2.74	30.96	33.01	34.47	22	39.8
qte size per partic.	102	14.44	0.54	14.11	14.45	14.77	12	15.5
steepness	102	0.09	0.01	0.09	0.09	0.10	0.06	0.11
slope	102	0.11	0.02	0.10	0.11	0.11	0.08	0.2
DS	102	10.31	0.87	9.81	10.27	10.73	8.55	15.35
DSS	102	0.0017	0.0003	0.0015	0.0017	0.0019	0.0012	0.003
mkt quality index	102	0.81	0.06	0.79	0.82	0.85	0.58	0.92
CRT 10	102	0.11	0.01	0.10	0.10	0.11	0.07	0.15
abs price change	102	0.017	0.002	0.016	0.017	0.018	0.010	0.024
mkt participants	102	8.63	0.62	8.30	8.69	9.07	5.07	9.85
trade size	100	6.12	1.23	5.51	6.00	6.80	2.50	10
trading volume	100	68.11	48.23	33.77	56.62	79.66	5.08	238.05
trading frequency	100	10.96	8.04	5.93	8.71	13.08	1.00	42.31
turnover ratio	100	0.75	0.78	0.28	0.47	0.96	0.04	3.97
NTQ	51	0.0010	0.0018	0.0006	0.0011	0.0015	-0.0085	0.0050
NTC	51	0.0071	0.0075	0.0043	0.0073	0.0109	-0.0212	0.0224

Table C.16 – Correlation Coefficients BTP 30 on-the-run (5 min freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*	*DS*	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*
best spread	1																
spread	0.6135*	1															
weighted spread	0.5661*	0.9182*	1														
best size	0.1697*	0.2165*	0.0320*	1													
second size	0.1785*	0.2896*	0.0558*	0.3098*	1												
worst size	-0.5587*	-0.0453*	-0.0231*	0.0463*	0.2366*	1											
quote size	-0.4952*	0.0821*	0.0430*	0.2430*	0.4389*	0.9712*	1										
average quote size	-0.2250*	0.1131*	0.0765*	0.4128*	0.6138*	0.7760*	0.8845*	1									
weighted depth	-0.1986*	0.2111*	0.0703*	0.5785*	0.6601*	0.7302*	0.8840*	0.9239*	1								
qte size per partic.	-0.5033*	-0.1223*	0.0407*	-0.0370*	-0.1010*	0.4644*	0.5250*	0.4563*	0.3465*	1							
steepness	-0.6911*	0.0415*	0.0213*	-0.1074*	0.0470*	0.6804*	0.6240*	0.2795*	0.3184*	0.3279*	1						
slope	0.2665*	-0.0561*	-0.0768*	-0.1809*	-0.3963*	-0.6757*	-0.7167*	-0.6959*	-0.6693*	-0.4463*	-0.3774*	1					
DS	0.2097*	-0.0821*	-0.0600*	-0.1800*	-0.3926*	-0.6986*	-0.7479*	-0.7350*	-0.6803*	-0.3143*	-0.4080*	0.7111*	1				
DSS	0.2258*	-0.2092*	-0.2120*	-0.1935*	-0.3898*	-0.6780*	-0.6236*	-0.5979*	-0.5914*	-0.4713*	-0.3736*	0.8558*	0.7665*	1			
mkt quality index	-0.4090*	-0.2070*	-0.2148*	0.3157*	0.4592*	0.7390*	0.7858*	0.8720*	0.7758*	0.4433*	0.1584*	-0.6446*	-0.6165*	-0.5130*	1		
CRT 10	0.8628*	0.5357*	0.5477*	0.0844*	0.1401*	-0.5201*	-0.4548*	-0.1552*	-0.1763*	-0.3615*	-0.4668*	0.3165*	0.1518*	0.2746*	-0.4609*	1	
abs price change	0.1087*	0.0173*	0.0314*	-0.0447*	-0.1039*	-0.1885*	-0.2053*	-0.1860*	-0.1820*	-0.0783*	-0.1197*	0.1172*	0.1403*	0.1074*	-0.1575*	0.0724*	1
mkt participants	-0.4379*	0.1348*	0.0345*	0.3112*	0.5189*	0.9127*	0.9738*	0.8699*	0.9123*	0.3643*	0.5906*	-0.6971*	-0.7337*	-0.6134*	0.7601*	-0.3970*	-0.2036*

Table C.17 – Correlation Coefficients BTP 5 on-the-run (5 min freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepnes s*	*slope*	*DS*	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*
best spread	1																
spread	0.6122*	1															
weighted spread	0.6459*	0.7950*	1														
best size	0.2433*	0.1288*	-0.1869*	1													
second size	-0.3251*	-0.0921*	-0.1819*	0.2177*	1												
worst size	-0.6276*	-0.0075	0.1259*	-0.3079*	0.2600*	1											
quote size	-0.3740*	-0.0131*	-0.1798*	0.4988*	0.8872*	0.4368*	1										
average quote size	-0.1831*	-0.2030*	-0.2648*	0.6724*	0.7743*	0.1038*	0.8778*	1									
weighted depth	-0.1537*	0.0331*	-0.2188*	0.7784*	0.7562*	0.1229*	0.9286*	0.9263*	1								
qte size per partic.	-0.2139*	-0.4067*	-0.3500*	0.0137*	0.0828*	-0.0496*	0.0443*	0.1344*	0.0460*	1							
steepness	-0.4823*	0.4447*	0.1936*	-0.2419*	0.2592*	0.6675*	0.3337*	-0.1257*	0.0991*	-0.1909*	1						
slope	0.3755*	0.1965*	0.1829*	-0.2157*	-0.6309*	-0.2959*	-0.6479*	-0.5952*	-0.5614*	-0.0946*	-0.1971*	1					
DS	0.2535*	-0.0414*	0.1476*	-0.2601*	-0.5854*	-0.2846*	-0.6408*	-0.5008*	-0.5710*	-0.0072	-0.3187*	0.5414*	1				
DSS	0.2856*	0.1356*	0.1870*	-0.2400*	-0.5570*	-0.2108*	-0.5142*	-0.4863*	-0.4760*	-0.1237*	-0.1168*	0.7612*	0.5578*	1			
mkt quality index	-0.2923*	-0.4375*	-0.3895*	0.5264*	0.7108*	0.1101*	0.7708*	0.9492*	0.7901*	0.2388*	-0.2428*	-0.5630*	-0.4161*	-0.4499*	1		
CRT 10	0.9618*	0.5526*	0.6170*	0.2095*	-0.3684*	-0.5811*	-0.4072*	-0.2143*	-0.1931*	-0.2099*	-0.4540*	0.4220*	0.2856*	0.3256*	-0.3200*	1	
abs price change	0.1502*	0.1075*	0.1869*	-0.1290*	-0.1834*	-0.0376*	-0.2100*	-0.2005*	-0.2087*	-0.0669*	-0.0266*	0.1365*	0.1307*	0.1303*	-0.1948*	0.1415*	1
mkt participants	-0.2600*	0.1872*	0.0031	0.4277*	0.7364*	0.4340*	0.8771*	0.7102*	0.8047*	-0.3907*	0.4204*	-0.5557*	-0.5790*	-0.4379*	0.5598*	-0.2816*	-0.1635*

Table C.18 – Correlation Coefficients BTP 3 on-the-run (5 min freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*	*DS*	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*
best spread	1																
spread	0.5855*	1															
weighted spread	0.5926*	0.7502*	1														
best size	0.3453*	0.1741*	-0.1614*	1													
second size	-0.4634*	-0.2194*	-0.2482*	0.1146*	1												
worst size	-0.7163*	-0.0724*	0.0031	-0.3721*	0.3582*	1											
quote size	-0.3699*	-0.0719*	-0.2411*	0.5061*	0.8833*	0.3670*	1										
average quote size	-0.1092*	-0.2092*	-0.2653*	0.6999*	0.7151*	-0.0064	0.8764*	1									
weighted depth	-0.1005*	0.0144*	-0.2454*	0.7919*	0.6824*	0.0496*	0.9254*	0.9329*	1								
qte size per partic.	-0.4815*	-0.4634*	-0.2212*	-0.2629*	0.2577*	0.3409*	0.1658*	0.1170*	0.0017	1							
steepness	-0.5647*	0.3848*	0.1241*	-0.3182*	0.2966*	0.7183*	0.2650*	-0.2027*	0.0148*	0.0408*	1						
slope	0.3854*	0.3322*	0.3119*	-0.2321*	-0.6278*	-0.2314*	-0.6404*	-0.5972*	-0.5562*	-0.2585*	-0.0991*	1					
DS	0.3375*	0.0731*	0.2521*	-0.1563*	-0.5447*	-0.3079*	-0.5722*	-0.4092*	-0.4674*	-0.1337*	-0.2977*	0.5025*	1				
DSS	0.2966*	0.2251*	0.2928*	-0.2417*	-0.5424*	-0.1422*	-0.4778*	-0.4580*	-0.4464*	-0.2354*	-0.0210*	0.7726*	0.5365*	1			
mkt quality index	-0.2236*	-0.4378*	-0.3686*	0.5393*	0.6976*	0.0230*	0.7863*	0.9491*	0.8019*	0.2509*	-0.2910*	-0.5829*	-0.3595*	-0.4335*	1		
CRT 10	0.9687*	0.5615*	0.6004*	0.3084*	-0.4902*	-0.6710*	-0.3992*	-0.1430*	-0.1377*	-0.4722*	-0.5248*	0.4269*	0.3570*	0.3271*	-0.2552*	1	
abs price change	0.1135*	0.0820*	0.1400*	-0.1208*	-0.1731*	-0.0411*	-0.2084*	-0.1960*	-0.2012*	-0.0143*	-0.0151*	0.1413*	0.1109*	0.1244*	-0.1835*	0.1121*	1
mkt participants	-0.2338*	0.0676*	-0.1959*	0.6259*	0.7777*	0.2310*	0.9559*	0.8518*	0.9467*	-0.0828*	0.2431*	-0.5897*	-0.5406*	-0.4496*	0.7130*	-0.2628*	-0.2108*

Table C.19 – Correlation Coefficients CTZ on-the-run (5 min freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*	*DS*	*DSS*	*mkt qual ind*	*mkt qual ind2*	*CRT 10*	*abs pr change*
best spread	1																	
spread	0.5847*	1																
weighted spread	0.6434*	0.8843*	1															
best size	0.0091*	0.0224*	-0.1555*	1														
second size	-0.1073*	-0.0694*	-0.2539*	0.0447*	1													
worst size	-0.4823*	0.1108*	-0.0709*	0.0277*	0.1388*	1												
quote size	-0.4994*	0.0586*	-0.1688*	0.2041*	0.3204*	0.9677*	1											
average quote size	-0.3307*	-0.2831*	-0.3960*	0.3211*	0.4309*	0.6190*	0.7005*	1										
weighted depth	-0.4746*	-0.0310*	-0.2961*	0.2968*	0.4016*	0.9067*	0.9757*	0.7667*	1									
qte size per partic.	-0.1623*	-0.2020*	-0.1043*	0.1833*	0.1025*	0.0768*	0.1504*	0.4943*	0.1488*	1								
steepness	-0.3361*	0.5316*	0.2964*	0.0276*	0.0659*	0.6446*	0.6211*	0.0817*	0.5095*	-0.1207*	1							
slope	0.4197*	0.1584*	0.2152*	-0.0525*	-0.2360*	-0.5593*	-0.5764*	-0.4999*	-0.5767*	-0.1724*	-0.2544*	1						
DS	0.3182*	0.0573*	0.2092*	-0.2019*	-0.2978*	-0.6249*	-0.6770*	-0.6881*	-0.6923*	-0.3117*	-0.2862*	0.5555*	1					
DSS	0.4238*	0.1047*	0.2173*	-0.1139*	-0.2532*	-0.6102*	-0.6076*	-0.5256*	-0.6147*	-0.2178*	-0.3076*	0.8368*	0.6464*	1				
mkt quality index	-0.4435*	-0.6810*	-0.6704*	0.1991*	0.3220*	0.3289*	0.3950*	0.8375*	0.4879*	0.4704*	-0.2660*	-0.3969*	-0.4828*	-0.3892*	1			
mkt qual index 2	-0.6295*	-0.3254*	-0.4757*	0.1734*	0.3274*	0.8514*	0.8946*	0.7963*	0.9157*	0.2289*	0.3246*	-0.5827*	-0.6558*	-0.6027*	0.6960*	1		
CRT 10	0.9400*	0.5459*	0.6722*	-0.1213*	-0.1490*	-0.5098*	-0.5442*	-0.3798*	-0.5504*	-0.0701*	-0.3016*	0.4627*	0.3680*	0.4596*	-0.4859*	-0.6990*	1	
abs price change	0.1608*	0.0740*	0.1349*	-0.0478*	-0.0871*	-0.1980*	-0.2155*	-0.1535*	-0.2247*	0.0289*	-0.0868*	0.1585*	0.1428*	0.1708*	-0.1336*	-0.2255*	0.1892*	1
mkt participants	-0.4440*	0.1422*	-0.1360*	0.1461*	0.2820*	0.8794*	0.9073*	0.5009*	0.8905*	-0.2085*	0.6598*	-0.5268*	-0.5450*	-0.5558*	0.2059*	0.7643*	-0.4902*	-0.2326*

Table C.20 – Correlation Coefficients BTP 10ind on-the-run (5 min freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*	*DS*	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*
best spread	1																
spread	0.5699*	1															
weighted spread	0.4516*	0.9009*	1														
best size	0.2064*	0.1773*	0.0057	1													
second size	0.2090*	0.1896*	0.0297*	0.0882*	1												
worst size	-0.4146*	0.1173*	0.2262*	-0.0399*	0.0157*	1											
quote size	-0.3737*	0.2115*	0.2715*	0.0877*	0.1777*	0.9810*	1										
average quote size	-0.001	0.2055*	0.2707*	0.2344*	0.4046*	0.6723*	0.7553*	1									
weighted depth	0.0459*	0.3335*	0.2396*	0.5183*	0.3972*	0.6728*	0.7968*	0.7862*	1								
qte size per partic.	-0.3064*	0.0149*	0.2410*	-0.0672*	-0.0821*	0.3387*	0.3846*	0.3839*	0.1837*	1							
steepness	-0.7279*	0.0336*	0.0511*	-0.0935*	-0.0943*	0.6232*	0.5878*	0.0863*	0.2017*	0.2372*	1						
slope	0.0980*	-0.1825*	-0.2951*	-0.0529*	-0.2112*	-0.5421*	-0.5709*	-0.5491*	-0.5101*	-0.4104*	-0.2605*	1					
DS	0.1199*	-0.1049*	-0.1862*	-0.0485*	-0.1790*	-0.6034*	-0.6292*	-0.6402*	-0.5153*	-0.2419*	-0.2430*	0.4312*	1				
DSS	0.0872*	-0.2922*	-0.3695*	-0.0826*	-0.2298*	-0.6584*	-0.6797*	-0.6430*	-0.6147*	-0.4031*	-0.2766*	0.8179*	0.5675*	1			
mkt quality index	-0.2415*	-0.2677*	-0.1583*	0.1401*	0.3037*	0.5916*	0.6026*	0.8613*	0.5761*	0.3482*	0.0366*	-0.4374*	-0.5732*	-0.4679*	1		
CRT 10	0.9618*	0.5308*	0.4348*	0.0996*	0.2178*	-0.4347*	-0.4023*	-0.0119*	-0.0134*	-0.3324*	-0.7229*	0.1229*	0.1142*	0.1084*	-0.2368*	1	
abs price change	0.0518*	-0.1035*	-0.1258*	-0.0159*	-0.0330*	-0.2428*	-0.2573*	-0.1955*	-0.2071*	-0.0919*	-0.1241*	0.1770*	0.1535*	0.1999*	-0.1335*	0.0673*	1
mkt participants	-0.3078*	0.2545*	0.2391*	0.1386*	0.2436*	0.9187*	0.9584*	0.7102*	0.8248*	0.1418*	0.5548*	-0.5260*	-0.5973*	-0.6552*	0.5398*	-0.3260*	-0.2495*

Table C.21 – Correlation Coefficients BTP 30 on-the-run (weekly freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*
best spread	1											
spread	0.9021*	1										
weighted spread	0.8579*	0.9597*	1									
best size	0.1999*	0.0342	-0.1279	1								
second size	0.3393*	0.2161*	0.042	0.5937*	1							
worst size	-0.3613*	-0.2351*	-0.2586*	0.2559*	0.3790*	1						
quote size	-0.2497*	-0.1696	-0.2398*	0.4025*	0.5831*	0.9632*	1					
average quote size	0.1468	0.0915	0.0151	0.5567*	0.7684*	0.7763*	0.8832*	1				
weighted depth	0.0504	-0.0058	-0.1508	0.6938*	0.8314*	0.7538*	0.8880*	0.9439*	1			
qte size per partic.	-0.2191*	-0.1713	-0.1272	0.2721*	0.2595*	0.6669*	0.6679*	0.6216*	0.5332*	1		
steepness	-0.1429	0.0934	0.1042	-0.1287	0.1655	0.4848*	0.4481*	0.2503*	0.2323*	0.2291*	1	
slope	-0.1296	-0.0391	-0.0394	-0.3642*	-0.5515*	-0.5587*	-0.6029*	-0.7242*	-0.6336*	-0.5763*	-0.1305	1
DS	-0.3136*	-0.3095*	-0.2764*	-0.3112*	-0.6836*	-0.6131*	-0.6880*	-0.8118*	-0.7080*	-0.4826*	-0.5825*	0.7224*
DSS	-0.0363	0.0609	0.0986	-0.2875*	-0.4915*	-0.4516*	-0.5011*	-0.5836*	-0.5397*	-0.4452*	0.0123	0.6680*
mkt quality index	-0.4519*	-0.5475*	-0.5998*	0.3624*	0.164	0.4514*	0.4588*	0.3921*	0.4457*	0.3975*	-0.4924*	-0.2889*
CRT 10	0.7641*	0.7497*	0.7515*	0.0645	0.4119*	-0.0435	0.0519	0.3256*	0.1937	-0.0177	0.4550*	-0.2376*
abs price change	0.076	0.1472	0.1707	-0.2372*	-0.3425*	-0.2372*	-0.3166*	-0.3238*	-0.3439*	-0.2057*	-0.3048*	0.2122*
mkt participants	-0.2316*	-0.1445	-0.2547*	0.3617*	0.6001*	0.8865*	0.9359*	0.8046*	0.8557*	0.3737*	0.4403*	-0.4948*
trade size	-0.2263*	-0.2671*	-0.2675*	0.2011*	0.0694	0.2850*	0.2852*	0.2493*	0.2606*	0.2687*	0.0174	-0.1719
trad volume	-0.3988*	-0.2381*	-0.1472	-0.4230*	-0.3380*	0.0743	-0.0296	-0.2110*	-0.2766*	0.0705	0.1771	0.1269
trad frequency	-0.3487*	-0.1683	-0.0689	-0.4597*	-0.2838*	0.1271	0.0238	-0.158	-0.2430*	0.0891	0.3352*	0.0882
turnover	-0.1605	0.0015	0.1158	-0.5087*	-0.3112*	-0.0721	-0.171	-0.2822*	-0.3846*	-0.077	0.3218*	0.1994*
NTQ	0.1831	0.1998*	0.2363*	-0.1977*	-0.2378*	-0.2186*	-0.2436*	-0.1512	-0.2457*	-0.1596	-0.2196*	0.1922
NTC	0.1398	0.1798	0.2327*	-0.2587*	-0.3207*	-0.2043*	-0.2516*	-0.1866	-0.2889*	-0.172	-0.2069*	0.2209*

	DS	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*	*mkt partic.*	*trade size*	*trad volume*	*trad freq.*	*turnover*	*NTQ*	*NTC*
DS	1											
DSS	0.4576*	1										
mkt quality index	0.1244	-0.4103*	1									
CRT 10	-0.6699*	-0.0421	-0.6903*	1								
abs price change	0.3299*	0.1416	0.0307	-0.1838	1							
mkt participants	-0.6189*	-0.4284*	0.4034*	0.0505	-0.2836*	1						
trade size	-0.0854	-0.2462*	0.2721*	-0.1105	0.0354	0.2402*	1					
trad volume	0.1572	0.0046	0.0269	-0.2409*	0.1911	-0.0582	0.2261*	1				
trad frequency	0.0295	0.0194	-0.0977	-0.1016	0.0919	-0.0074	0.0774	0.9548*	1			
turnover	0.0519	0.1755	-0.3092*	0.0553	0.1642	-0.1839	0.0409	0.8526*	0.8853*	1		
NTQ	0.1394	0.2132*	-0.0671	0.0375	0.2088*	-0.2389*	-0.2105*	-0.0524	-0.0496	0.0086	1	
NTC	0.1668	0.2457*	-0.0741	0.0107	0.3101*	-0.2389*	-0.1147	0.011	-0.0086	0.0535	0.9692*	1

Table C.22 – Correlation Coefficients BTP 5 on-the-run (weekly freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepnes s*	*slope*
best spread	1											
spread	0.8425*	1										
weighted spread	0.9313*	0.9215*	1									
best size	-0.4845*	-0.6526*	-0.6793*	1								
second size	-0.3042*	-0.4942*	-0.3854*	0.7349*	1							
worst size	0.4590*	0.6311*	0.7015*	-0.4730*	-0.0518	1						
quote size	-0.2713*	-0.4041*	-0.3226*	0.7571*	0.9668*	0.0898	1					
average quote size	-0.3897*	-0.6630*	-0.5149*	0.8395*	0.9430*	-0.2161*	0.9163*	1				
weighted depth	-0.3815*	-0.5471*	-0.4969*	0.8980*	0.9465*	-0.1509	0.9656*	0.9528*	1			
qte size per partic.	-0.4618*	-0.5661*	-0.5224*	0.4373*	0.4167*	-0.3055*	0.3660*	0.4658*	0.4273*	1		
steepness	0.3139*	0.7702*	0.5308*	-0.6097*	-0.5316*	0.5590*	-0.4256*	-0.7318*	-0.5471*	-0.4122*	1	
slope	0.3470*	0.5682*	0.3765*	-0.6080*	-0.8271*	-0.0236	-0.8183*	-0.8525*	-0.7933*	-0.4529*	0.6188*	1
DS	0.3519*	0.3944*	0.3981*	-0.7082*	-0.8318*	-0.0062	-0.8609*	-0.7573*	-0.8531*	-0.3563*	0.3129*	0.7790*
DSS	-0.0331	-0.102	0.0052	-0.1021	-0.071	0.0217	-0.0808	0.0051	-0.0912	-0.0645	-0.1614	-0.0616
mkt quality index	-0.5643*	-0.8234*	-0.6896*	0.8482*	0.8565*	-0.3894*	0.8055*	0.9636*	0.8861*	0.5168*	-0.8063*	-0.8037*
CRT 10	0.9823*	0.8506*	0.9390*	-0.5574*	-0.3512*	0.4590*	-0.3301*	-0.4421*	-0.4471*	-0.4771*	0.3600*	0.4053*
abs price change	0.7057*	0.6550*	0.6921*	-0.3865*	-0.2576*	0.3840*	-0.2152*	-0.3228*	-0.3063*	-0.3763*	0.3001*	0.2412*
mkt participants	0.3013*	0.3487*	0.3351*	0.0636	0.2319*	0.4105*	0.3169*	0.1273	0.2235*	-0.7579*	0.1933*	-0.0848
trade size	-0.0729	-0.3433*	-0.1954*	0.4814*	0.5411*	-0.094	0.5311*	0.5819*	0.5483*	0.4999*	-0.5223*	-0.6023*
trad volume	-0.4859*	-0.2867*	-0.4008*	0.0282	-0.1578	-0.2540*	-0.1746*	-0.1004	-0.1025	0.1434	0.0761	0.162
trad frequency	-0.4006*	-0.1412	-0.2959*	-0.1159	-0.3164*	-0.2084*	-0.3272*	-0.2772*	-0.2630*	-0.0491	0.2314*	0.3543*
turnover	-0.1442	-0.0762	-0.111	-0.078	-0.2177*	-0.1466	-0.2286*	-0.1467	-0.1812*	-0.0421	0.0367	0.2384*
NTQ	0.2596*	0.3268*	0.2945*	-0.1968*	-0.1249	0.2346*	-0.0796	-0.1973*	-0.139	-0.0623	0.2602*	0.0854
NTC	0.2060*	0.2514*	0.2391*	-0.156	-0.0841	0.2079*	-0.0437	-0.1403	-0.0976	-0.003	0.1874*	0.0163

	DS	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*	*mkt partic.*	*trade size*	*trad volume*	*trad freq.*	*turnover*	*NTQ*	*NTC*
DS	1											
DSS	0.0266	1										
mkt quality index	-0.6754*	0.0541	1									
CRT 10	0.4120*	-0.0396	-0.6099*	1								
abs price change	0.2423*	0.0229	-0.4329*	0.6841*	1							
mkt participants	-0.2466*	-0.0338	-0.011	0.2723*	0.2558*	1						
trade size	-0.4703*	0.0751	0.5436*	-0.1643	-0.0956	-0.1801*	1					
trad volume	0.0958	-0.012	0.0352	-0.4426*	-0.2447*	-0.2978*	-0.1918*	1				
trad frequency	0.2492*	-0.0696	-0.1468	-0.3376*	-0.1821*	-0.1917*	-0.4679*	0.9361*	1			
turnover	0.2438*	0.0811	-0.0734	-0.121	-0.0032	-0.1562	-0.2262*	0.7384*	0.7635*	1		
NTQ	0.0815	0.043	-0.2664*	0.2390*	0.3310*	0.0495	-0.1122	-0.2379*	-0.1791*	-0.1675	1	
NTC	0.0428	0.0544	-0.1972*	0.1782*	0.3151*	0.0038	0.0032	-0.1955*	-0.1686	-0.1401	0.9499*	1

Table C.23 – Correlation Coefficients BTP 3 on-the-run (weekly freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*
best spread	1											
spread	0.7061*	1										
weighted spread	0.8312*	0.8984*	1									
best size	-0.4090*	-0.5478*	-0.7005*	1								
second size	-0.2983*	-0.4087*	-0.4504*	0.7787*	1							
worst size	0.1678*	0.6540*	0.5783*	-0.3930*	-0.0375	1						
quote size	-0.3363*	-0.3507*	-0.4626*	0.8544*	0.9678*	0.0169	1					
average quote size	-0.3604*	-0.6228*	-0.6153*	0.8976*	0.9212*	-0.3182*	0.9143*	1				
weighted depth	-0.3762*	-0.4575*	-0.5797*	0.9413*	0.9359*	-0.1634*	0.9787*	0.9494*	1			
qte size per partic.	-0.2556*	-0.3374*	-0.3301*	0.5938*	0.7728*	0.0774	0.7623*	0.7339*	0.7254*	1		
steepness	0.2287*	0.8388*	0.6017*	-0.4687*	-0.3538*	0.7814*	-0.2600*	-0.6134*	-0.3750*	-0.2702*	1	
slope	0.4552*	0.4983*	0.4750*	-0.5599*	-0.7406*	0.0356	-0.7115*	-0.7150*	-0.6849*	-0.5618*	0.3805*	1
DS	0.3490*	0.2999*	0.3938*	-0.5947*	-0.7611*	-0.0705	-0.7581*	-0.6668*	-0.7229*	-0.5288*	0.1719*	0.8743*
DSS	0.2384*	0.3411*	0.2892*	-0.2026*	-0.2502*	0.1115	-0.2141*	-0.2817*	-0.2226*	-0.2254*	0.2740*	0.1850*
mkt quality index	-0.5196*	-0.8209*	-0.7804*	0.8567*	0.7921*	-0.5017*	0.7719*	0.9474*	0.8451*	0.6472*	-0.7594*	-0.6481*
CRT 10	0.9799*	0.7487*	0.8828*	-0.4973*	-0.3704*	0.2219*	-0.4072*	-0.4416*	-0.4575*	-0.3108*	0.3015*	0.4821*
abs price change	0.3654*	0.4882*	0.4823*	-0.4095*	-0.3955*	0.1813*	-0.3919*	-0.4673*	-0.4181*	-0.2775*	0.4117*	0.3915*
mkt participants	-0.3483*	-0.2990*	-0.4626*	0.8187*	0.8578*	-0.0267	0.9131*	0.8118*	0.9074*	0.4471*	-0.1997*	-0.6971*
trade size	-0.2395*	-0.2192*	-0.3334*	0.4182*	0.4275*	-0.0426	0.4349*	0.3839*	0.4432*	0.4280*	-0.094	-0.2506*
trad volume	0.0836	0.2688*	0.2436*	-0.3806*	-0.4610*	0.1749*	-0.4298*	-0.4595*	-0.4353*	-0.2363*	0.3436*	0.3892*
trad frequency	0.1194	0.3342*	0.3235*	-0.4693*	-0.5589*	0.2058*	-0.5218*	-0.5511*	-0.5305*	-0.3252*	0.4030*	0.4681*
turnover	0.1646*	0.4444*	0.4043*	-0.4837*	-0.6072*	0.2919*	-0.5347*	-0.6023*	-0.5493*	-0.3822*	0.5084*	0.5511*
NTQ	0.0304	0.2012*	0.1714*	-0.2854*	-0.2139*	0.1395	-0.2266*	-0.3081*	-0.2583*	-0.1401	0.2499*	0.0717
NTC	-0.0059	0.1680*	0.1203	-0.2257*	-0.1556	0.1406	-0.1663*	-0.2558*	-0.1966*	-0.0547	0.2370*	0.0397

	DS	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*	*mkt partic.*	*trade size*	*trad volume*	*trad freq.*	*turnover*	*NTQ*	*NTC*
DS	1											
DSS	0.1417	1										
mkt quality index	-0.5454*	-0.3253*	1									
CRT 10	0.3760*	0.2599*	-0.5932*	1								
abs price change	0.3318*	0.2716*	-0.4995*	0.4274*	1							
mkt participants	-0.7700*	-0.1508	0.6725*	-0.4090*	-0.3780*	1						
trade size	-0.2980*	-0.1782*	0.3494*	-0.3029*	-0.1788*	0.3247*	1					
trad volume	0.3653*	0.1116	-0.4143*	0.1406	0.2200*	-0.4556*	0.0992	1				
trad frequency	0.4546*	0.1635*	-0.5002*	0.1968*	0.2975*	-0.5291*	-0.0864	0.9723*	1			
turnover	0.5295*	0.2498*	-0.5728*	0.2526*	0.3704*	-0.5174*	-0.1238	0.8100*	0.8642*	1		
NTQ	0.0855	0.113	-0.3069*	0.0557	0.3699*	-0.2058*	-0.1133	-0.0245	0.0194	0.0089	1	
NTC	0.053	0.0896	-0.2571*	0.0138	0.3409*	-0.1726*	0.0207	-0.0039	0.0132	-0.0035	0.9601*	1

Table C.24 – Correlation Coefficients CTZ on-the-run (weekly freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*
best spread	1											
spread	0.7682*	1										
weighted spread	0.6322*	0.9173*	1									
best size	-0.1760*	-0.2512*	-0.3577*	1								
second size	-0.6085*	-0.6012*	-0.7050*	0.6162*	1							
worst size	-0.5054*	-0.2189*	-0.2062*	0.1634	0.4611*	1						
quote size	-0.6907*	-0.3869*	-0.3315*	0.3292*	0.6423*	0.9705*	1					
average quote size	-0.5033*	-0.6808*	-0.6500*	0.4380*	0.7608*	0.6864*	0.7146*	1				
weighted depth	-0.7644*	-0.6064*	-0.5846*	0.4463*	0.8067*	0.8517*	0.9492*	0.8172*	1			
qte size per partic.	-0.126	-0.1446	-0.0695	0.2548*	0.3507*	0.6333*	0.5550*	0.6936*	0.4733*	1		
steepness	0.2234*	0.6822*	0.5778*	-0.1284	-0.2100*	0.2693*	0.1792*	-0.3781*	-0.061	-0.0216	1	
slope	0.6856*	0.5360*	0.3743*	-0.2154*	-0.4541*	-0.6507*	-0.6788*	-0.6166*	-0.7123*	-0.2985*	0.1313	1
DS	0.5531*	0.4769*	0.4574*	-0.4198*	-0.6511*	-0.8022*	-0.8594*	-0.8634*	-0.8653*	-0.6799*	0.1318	0.6767*
DSS	0.8469*	0.5187*	0.3400*	-0.1948*	-0.5326*	-0.6842*	-0.7652*	-0.4503*	-0.7659*	-0.1713*	0.1516	0.9353*
mkt quality index	-0.6302*	-0.8739*	-0.8268*	0.3715*	0.7412*	0.4715*	0.5697*	0.9238*	0.7411*	0.4710*	-0.5877*	-0.5642*
mkt qual index 2	-0.7989*	-0.8011*	-0.7451*	0.3695*	0.7721*	0.7174*	0.8284*	0.8901*	0.9287*	0.4725*	-0.3417*	-0.6848*
CRT 10	0.9610*	0.7821*	0.7031*	-0.2678*	-0.6872*	-0.4672*	-0.6859*	-0.5376*	-0.7901*	-0.0974	0.2994*	0.5995*
abs price change	0.4367*	0.4887*	0.5690*	-0.3621*	-0.4910*	-0.1589	-0.2954*	-0.3287*	-0.4283*	0.088	0.2413*	0.2232*
mkt participants	-0.7368*	-0.3770*	-0.3689*	0.2216*	0.5140*	0.6386*	0.7573*	0.3315*	0.7728*	-0.113	0.2271*	-0.6266*
trade size	0.0163	-0.0237	-0.1193	0.4495*	0.2368*	0.0147	0.1003	0.1496	0.1246	0.2275*	0.0102	0.1673*
trad volume	-0.1675*	-0.0623	-0.0783	0.1362	0.1083	0.1285	0.1464	0.1164	0.1163	0.2566*	0.1208	0.09
trad frequency	-0.2314*	-0.0933	-0.072	-0.0046	0.0598	0.1917*	0.1778*	0.1353	0.13	0.2779*	0.1327	0.0277
turnover	0.0474	0.0294	0.0484	-0.0701	-0.1571	-0.1618	-0.1729*	-0.1007	-0.1863*	0.1376	0.0113	0.2903*
NTQ	0.2592*	0.2879*	0.2908*	-0.1039	-0.3271*	-0.1679*	-0.2172*	-0.3446*	-0.2587*	-0.1557	0.1795*	0.1736*
NTC	0.3995*	0.4580*	0.4292*	-0.0409	-0.3515*	-0.1375	-0.1883*	-0.3780*	-0.2854*	-0.0565	0.3096*	0.2552*

	DS	*DSS*	*mkt qual ind*	*mkt qual ind2*	*CRT 10*	*abs price change*	*mkt partic.*	*trade size*	*trad volume*	*trad freq.*	*turnover*	*NTQ*
DS	1											
DSS	0.7312*	1										
mkt quality index	-0.7208*	-0.4731*	1									
mkt qual index 2	-0.8268*	-0.7016*	0.9139*	1								
CRT 10	0.5490*	0.8225*	-0.6704*	-0.8248*	1							
abs price change	0.3127*	0.3199*	-0.4670*	-0.4970*	0.4957*	1						
mkt participants	-0.4910*	-0.7852*	0.3340*	0.6323*	-0.7464*	-0.4323*	1					
trade size	-0.1019	0.1447	0.0954	0.0863	-0.0868	-0.0991	-0.0915	1				
trad volume	-0.0724	0.0863	0.0875	0.1123	-0.1505	0.0853	-0.0727	0.5196*	1			
trad frequency	-0.0895	0.0324	0.1127	0.1474	-0.1749*	0.1384	-0.0531	0.2744*	0.9438*	1		
turnover	0.2152*	0.2679*	-0.1086	-0.1657*	0.0928	0.2690*	-0.3540*	0.3235*	0.6504*	0.6195*	1	
NTQ	0.3163*	0.1655*	-0.3814*	-0.3380*	0.2629*	0.3722*	-0.1374	-0.2099*	-0.1385	-0.0903	0.022	1
NTC	0.3059*	0.2641*	-0.4776*	-0.4088*	0.3885*	0.4524*	-0.1984*	-0.025	-0.0655	-0.0637	0.0583	0.8662*

Table C.25 – Correlation Coefficients BTP 10ind on-the-run (weekly freq)

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*
best spread	1											
spread	0.8382*	1										
weighted spread	0.7847*	0.9405*	1									
best size	-0.1052	-0.2401*	-0.3420*	1								
second size	0.162	-0.0688	-0.2338*	0.3902*	1							
worst size	-0.5833*	-0.3907*	-0.2946*	0.0142	0.1099	1						
quote size	-0.5462*	-0.3938*	-0.3373*	0.174	0.2755*	0.9782*	1					
average quote size	0.1989*	0.0728	0.1195	0.137	0.5430*	0.5645*	0.6333*	1				
weighted depth	-0.1215	-0.2577*	-0.3447*	0.6332*	0.7399*	0.5494*	0.6955*	0.7281*	1			
qte size per partic.	-0.3821*	-0.1681	-0.0851	0.0651	0.0408	0.7335*	0.7288*	0.5003*	0.3696*	1		
steepness	-0.8550*	-0.5192*	-0.5221*	-0.0036	-0.2042*	0.5215*	0.4699*	-0.3214*	0.0264	0.3040*	1	
slope	0.006	-0.0154	-0.0249	-0.2299*	-0.4872*	-0.6219*	-0.6953*	-0.8094*	-0.7267*	-0.5677*	0.0439	1
DS	0.0042	-0.0968	-0.1056	0.0379	-0.3162*	-0.6515*	-0.6745*	-0.7721*	-0.5527*	-0.6033*	-0.0209	0.7653*
DSS	-0.2971*	-0.2999*	-0.3039*	-0.0593	-0.3141*	-0.3686*	-0.4193*	-0.7542*	-0.4670*	-0.4199*	0.3809*	0.6978*
mkt quality index	-0.2284*	-0.4097*	-0.3392*	0.2472*	0.4396*	0.6702*	0.7280*	0.8359*	0.7252*	0.5569*	-0.1076	-0.6850*
CRT 10	0.9635*	0.7921*	0.7565*	-0.2327*	0.1581	-0.5917*	-0.5728*	0.1534	-0.1915	-0.4309*	-0.7849*	0.0612
abs price change	-0.0488	-0.033	-0.0439	0.0108	0.0804	-0.0053	0.0022	0.0262	0.02	0.1196	0.072	-0.1364
mkt participants	-0.4739*	-0.3529*	-0.3424*	0.1994*	0.3558*	0.8952*	0.9342*	0.6021*	0.7366*	0.4639*	0.4334*	-0.6945*
trade size	-0.0376	-0.0811	-0.0678	0.2383*	0.1474	0.1924	0.2381*	0.3221*	0.2715*	0.3717*	-0.1001	-0.2104*
trad volume	-0.2993*	-0.1887	-0.1795	0.04	-0.0747	0.0447	0.0351	-0.2078*	-0.0809	0.1313	0.2780*	0.0566
trad frequency	-0.3000*	-0.185	-0.1643	0.0043	-0.1275	0.0034	-0.0194	-0.2714*	-0.1487	0.0477	0.3100*	0.0992
turnover	-0.4312*	-0.3664*	-0.3100*	0.1831	-0.0636	0.1453	0.1413	-0.2158*	0.0228	0.1315	0.4489*	0.0452
NTQ	-0.1632	-0.1238	-0.1085	0.0568	-0.0926	0.0384	0.0264	-0.1189	0.0159	0.0007	0.2602	0.0676
NTC	-0.2236	-0.1909	-0.1977	0.1692	-0.102	0.0303	0.0303	-0.1861	0.0526	0.0092	0.2821*	0.1403

	DS	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*	*mkt partic.*	*trade size*	*trad volume*	*trad freq.*	*turnover*	*NTQ*	*NTC*
DS	1											
DSS	0.7087*	1										
mkt quality index	-0.6205*	-0.5923*	1									
CRT 10	0.0226	-0.1853	-0.2956*	1								
abs price change	-0.1023	0.0337	0.01	-0.0018	1							
mkt participants	-0.6443*	-0.4058*	0.6671*	-0.4981*	-0.0361	1						
trade size	-0.2262*	-0.1842	0.3508*	-0.1145	-0.0193	0.1257	1					
trad volume	0.081	0.1375	-0.0841	-0.2812*	0.3245*	-0.023	0.1035	1				
trad frequency	0.113	0.1679	-0.1615	-0.2596*	0.3288*	-0.0556	-0.1178	0.9465*	1			
turnover	0.1254	0.2796*	-0.0858	-0.3896*	0.2094*	0.078	0.0511	0.7854*	0.7756*	1		
NTQ	0.0993	0.1804	-0.0825	-0.0868	0.0313	0.0238	-0.2368	0.0914	0.1079	0.087	1	
NTC	0.1628	0.2117	-0.0547	-0.2002	-0.0058	0.0123	-0.1779	0.0806	0.0582	0.0846	0.8470*	1

Table C.26 – Summary Statistics off-the-run (weekly freq - yields) [1]

		# obs.	mean	sd	p25	p50	p75	min	max
absolute price change	*BTP 30*	98	0.0019	0.0003	0.0016	0.0018	0.0020	0.0012	0.0027
	BTP 10	135	0.0018	0.0003	0.0016	0.0018	0.0020	0.0010	0.0028
	BTP 5	133	0.0020	0.0005	0.0017	0.0020	0.0022	0.0012	0.0039
	BTP 3	149	0.0017	0.0003	0.0015	0.0017	0.0019	0.0010	0.0026
	CTZ	141	0.0013	0.0003	0.0011	0.0013	0.0016	0.0006	0.0023
	BTP 10 ind	81	0.0020	0.0003	0.0017	0.0019	0.0021	0.0012	0.0029
market particip.	*BTP 30*	102	10.69	0.88	10.02	10.66	11.36	7.42	12.96
	BTP 10	145	19.13	1.65	18.36	19.40	20.10	7.77	21.55
	BTP 5	134	17.17	3.14	14.59	18.02	19.88	8.18	21.89
	BTP 3	151	13.87	1.28	13.03	14.17	14.83	9.58	16.17
	CTZ	143	12.45	1.74	11.84	12.67	13.36	1.02	15.37
	BTP 10 ind	102	8.77	0.75	8.37	8.77	9.20	5.07	10.52

Table C.27 – Summary Statistics off-the-run (weekly freq - yields) [2]

		# obs.	mean	sd	p25	p50	p75	min	max
best spread	*BTP 30*	98	0.0061	0.0007	0.0056	0.0060	0.0066	0.0049	0.0079
	BTP 10	135	0.0033	0.0003	0.0030	0.0033	0.0035	0.0026	0.0041
	BTP 5	133	0.0053	0.0007	0.0047	0.0052	0.0057	0.0041	0.0073
	BTP 3	149	0.0071	0.0010	0.0065	0.0070	0.0076	0.0052	0.0106
	CTZ	141	0.0042	0.0010	0.0034	0.0041	0.0047	0.0026	0.0074
	BTP 10 ind	81	0.0125	0.0021	0.0113	0.0125	0.0140	0.0085	0.0172
spread	*BTP 30*	98	0.0097	0.0008	0.0092	0.0095	0.0101	0.0085	0.0114
	BTP 10	135	0.0064	0.0004	0.0061	0.0064	0.0067	0.0057	0.0076
	BTP 5	133	0.0101	0.0009	0.0094	0.0099	0.0108	0.0087	0.0130
	BTP 3	149	0.0142	0.0014	0.0134	0.0142	0.0148	0.0115	0.0207
	CTZ	141	0.0132	0.0022	0.0115	0.0132	0.0145	0.0086	0.0214
	BTP 10 ind	81	0.0235	0.0020	0.0228	0.0238	0.0249	0.0181	0.0272
weighted spread	*BTP 30*	98	0.0095	0.0007	0.0090	0.0093	0.0099	0.0084	0.0113
	BTP 10	135	0.0059	0.0004	0.0055	0.0059	0.0062	0.0051	0.0071
	BTP 5	133	0.0094	0.0009	0.0086	0.0093	0.0103	0.0080	0.0125
	BTP 3	149	0.0135	0.0014	0.0126	0.0135	0.0141	0.0108	0.0204
	CTZ	141	0.0112	0.0017	0.0098	0.0110	0.0125	0.0083	0.0162
	BTP 10 ind	81	0.0239	0.0019	0.0233	0.0243	0.0252	0.0185	0.0268

Table C.28 – Summary Statistics off-the-run (weekly freq - yields) [3]

		# obs.	mean	sd	p25	p50	p75	min	max
best size	*BTP 30*	102	7.28	0.91	6.60	7.09	7.75	5.69	10.12
	BTP 10	145	38.55	5.65	35.70	39.42	41.89	11.79	48.78
	BTP 5	134	44.55	7.54	38.72	44.71	50.31	25.26	59.24
	BTP 3	151	52.90	10.09	45.93	53.16	59.81	29.87	76.58
	CTZ	143	10.39	2.76	8.65	10.19	11.98	5.35	25.17
	BTP 10 ind	102	10.76	1.24	9.93	10.63	11.27	8.58	15.01
second size	*BTP 30*	102	11.36	2.583	9.078	11.11	13.09	7.196	17.839
	BTP 10	145	79.36	12.51	73.94	79.78	87.38	14.83	105.85
	BTP 5	134	87.16	13.33	80.90	88.64	93.85	36.04	120.71
	BTP 3	151	96.63	12.19	88.61	97.31	105.2	55.75	130.86
	CTZ	142	12.50	4.10	9.70	11.63	14.44	6.56	31.92
	BTP 10 ind	102	13.84	2.182	12.641	13.63	14.65	10.38	24.01
worst size	*BTP 30*	102	57.84	7.44	52.22	57.77	64.10	36.17	72.79
	BTP 10	145	41.07	6.96	36.59	41.26	44.95	14.83	59.34
	BTP 5	134	24.13	5.67	19.71	23.14	27.71	13.10	40.06
	BTP 3	151	17.20	4.97	13.58	16.97	20.52	4.25	29.09
	CTZ	142	87.45	13.87	80.15	86.54	94.08	29.58	151.15
	BTP 10 ind	102	103.82	11.49	98.34	104.13	110.17	44.55	128.96
quoted size	*BTP 30*	102	73.98	9.07	66.42	73.27	81.53	53.36	96.35
	BTP 10	145	156.65	17.78	149.93	158.99	166.94	39.86	187.76
	BTP 5	134	153.72	19.28	145.59	155.55	164.83	79.71	195.91
	BTP 3	151	164.89	20.06	150.11	167.32	179.75	100.45	211.40
	CTZ	143	108.84	18.62	99.78	109.67	117.79	9.62	179.84
	BTP 10 ind	102	127.11	12.28	120.59	127.53	134.04	62.90	153.13
average quote size	*BTP 30*	102	10.74	1.41	9.46	10.90	11.66	8.29	13.93
	BTP 10	145	45.93	5.99	43.21	46.63	49.39	11.77	57.52
	BTP 5	134	52.82	8.55	47.71	53.60	58.61	26.22	71.06
	BTP 3	151	62.91	9.58	56.81	63.41	69.87	37.02	83.24
	CTZ	143	10.57	1.87	9.26	10.50	11.59	7.06	18.15
	BTP 10 ind	102	15.41	1.01	14.79	15.39	16.04	11.37	17.93
qt size per participant	*BTP 30*	102	6.80	0.44	6.43	6.90	7.16	5.88	7.60
	BTP 10	145	8.24	0.57	8.05	8.28	8.53	4.73	9.38
	BTP 5	134	9.29	1.64	7.95	9.01	11.02	6.05	12.11
	BTP 3	151	11.95	0.71	11.59	11.93	12.34	10.32	13.81
	CTZ	143	8.92	1.08	8.17	8.80	9.63	6.79	13.32
	BTP 10 ind	102	14.42	0.56	14.07	14.44	14.78	11.91	15.52

Table C.29 – Summary Statistics off-the-run (weekly freq - yields) [4]

		# obs.	mean	sd	p25	p50	p75	min	max
steepness	*BTP 30*	98	0.0033	0.0004	0.0029	0.0033	0.0036	0.0024	0.0043
	BTP 10	135	0.0031	0.0003	0.0029	0.0031	0.0034	0.0026	0.0038
	BTP 5	133	0.0050	0.0004	0.0047	0.0050	0.0053	0.0040	0.0066
	BTP 3	149	0.0073	0.0007	0.0067	0.0072	0.0078	0.0057	0.0101
	CTZ	141	0.0113	0.0026	0.0095	0.0107	0.0124	0.0070	0.0208
	BTP 10 ind	81	0.0110	0.0017	0.0099	0.0105	0.0124	0.0075	0.0144
quote frequency	*BTP 30*	102	6.65	0.40	6.36	6.67	6.94	5.50	7.38
	BTP 10	145	3.40	0.19	3.30	3.40	3.49	2.80	3.99
	BTP 5	134	2.97	0.24	2.79	2.92	3.10	2.54	3.83
	BTP 3	151	2.70	0.18	2.57	2.67	2.80	2.31	3.47
	CTZ	143	10.18	1.41	9.45	10.32	10.94	0.72	13.31
	BTP 10 ind	102	8.15	0.60	7.84	8.19	8.58	5.21	9.30
slope	*BTP 30*	98	0.008	0.001	0.007	0.007	0.008	0.006	0.011
	BTP 10	135	0.004	0.000	0.003	0.004	0.004	0.003	0.006
	BTP 5	133	0.007	0.001	0.006	0.006	0.007	0.005	0.012
	BTP 3	149	0.009	0.002	0.008	0.009	0.010	0.006	0.019
	CTZ	141	0.013	0.004	0.011	0.013	0.015	0.008	0.029
	BTP 10 ind	81	0.012	0.002	0.011	0.012	0.013	0.010	0.027
DS	*BTP 30*	98	0.97	0.15	0.84	0.92	1.11	0.72	1.29
	BTP 10	135	0.43	0.07	0.38	0.41	0.46	0.33	0.70
	BTP 5	133	0.77	0.15	0.68	0.76	0.83	0.56	1.60
	BTP 3	149	1.28	0.26	1.12	1.24	1.41	0.87	2.70
	CTZ	141	7.46	2.00	5.94	7.09	8.42	3.65	14.98
	BTP 10 ind	81	1.23	0.13	1.14	1.21	1.30	0.99	1.84
DSS	*BTP 30*	85	0.0120	0.0017	0.0110	0.0119	0.0129	0.0084	0.0168
	BTP 10	135	0.0051	0.0010	0.0044	0.0048	0.0055	0.0037	0.0092
	BTP 5	129	0.0072	0.0026	0.0055	0.0066	0.0080	0.0043	0.0240
	BTP 3	149	0.0113	0.0077	0.0085	0.0099	0.0111	0.0075	0.0880
	CTZ	141	0.0192	0.0056	0.0148	0.0184	0.0221	0.0117	0.0417
	BTP 10 ind	81	0.0200	0.0035	0.0173	0.0199	0.0212	0.0153	0.0342
Market Quality Index 2	*BTP 30*	98	76.94	8.93	70.26	75.38	84.87	54.96	95.96
	BTP 10	135	247.33	29.44	228.73	253.10	268.44	159.03	298.00
	BTP 5	133	153.54	22.87	138.81	154.18	168.55	83.90	206.45
	BTP 3	149	117.51	16.28	108.04	118.72	129.87	75.26	164.85
	CTZ	141	86.58	20.07	70.09	84.03	99.73	42.15	140.88
	BTP 10 ind	81	54.88	7.45	50.76	53.56	57.96	24.69	75.35

Table C.30 – Summary Statistics off-the-run (weekly freq - yields) [5]

		# obs.	mean	sd	p25	p50	p75	min	max
trade size	*BTP 30*	89	3.59	0.41	3.33	3.54	3.86	2.50	4.50
	BTP 10	145	6.87	0.47	6.50	6.87	7.21	5.78	8.03
	BTP 5	129	6.30	0.75	5.95	6.43	6.81	3.89	8.08
	BTP 3	151	6.99	0.77	6.45	6.93	7.41	5.35	9.57
	CTZ	142	3.95	0.64	3.55	3.83	4.40	2.85	6.19
	BTP 10 ind	99	6.08	1.20	5.44	5.95	6.73	2.50	10
trading volume	*BTP 30*	89	46.23	43.116	22.58	32.40	56.52	6.51	322.22
	BTP 10	145	240.75	136.03	156.08	208.86	290.02	60.02	1256.11
	BTP 5	129	168.35	98.89	91.34	140.70	224.39	24.30	549.97
	BTP 3	151	221.58	140.60	123.12	191.46	277.7	35.07	988.25
	CTZ	142	173.27	127.56	79.53	141.97	206.25	23.91	792.28
	BTP 10 ind	99	65.72	47.579	30.946	51.98	79.09	5.30	238.05
trading frequency	*BTP 30*	89	10.97	9.67	5.62	8.14	13.25	1.80	63.82
	BTP 10	145	34.04	18.36	23.54	30.40	40.74	9.41	167.77
	BTP 5	129	27.80	19.00	14.19	22.37	37.00	3.92	117.25
	BTP 3	151	31.98	19.96	17.12	27.39	41.22	3.93	125
	CTZ	142	43.32	26.21	23.80	36.39	56.09	8.00	133.25
	BTP 10 ind	99	10.68	8.03	5.56	8.20	12.95	1	42.31
turnover ratio	*BTP 30*	89	0.27	0.23	0.14	0.20	0.32	0.04	1.76
	BTP 10	145	1.13	0.70	0.73	0.96	1.33	0.26	5.59
	BTP 5	128	1.62	1.56	0.58	1.22	2.10	0.15	10.37
	BTP 3	151	2.12	2.26	0.84	1.48	2.40	0.21	14.66
	CTZ	142	1.91	1.89	0.67	1.31	2.37	0.28	11.03
	BTP 10 ind	99	0.63	0.71	0.23	0.40	0.72	0.04	3.97
NTQ	*BTP 30*	81	0.003	0.005	0.001	0.003	0.004	-0.015	0.023
	BTP 10	134	0.001	0.001	0.001	0.001	0.002	-0.003	0.005
	BTP 5	127	0.002	0.003	0.001	0.002	0.003	-0.010	0.016
	BTP 3	148	0.002	0.002	0.001	0.002	0.004	-0.003	0.008
	CTZ	135	0.002	0.003	0.001	0.002	0.004	-0.005	0.011
	BTP 10 ind	72	0.008	0.014	0.004	0.007	0.012	-0.072	0.039
NTC	*BTP 30*	81	0.010	0.019	0.005	0.010	0.017	-0.080	0.069
	BTP 10	134	0.010	0.009	0.005	0.010	0.014	-0.018	0.039
	BTP 5	127	0.014	0.017	0.006	0.015	0.024	-0.049	0.061
	BTP 3	148	0.018	0.016	0.010	0.018	0.028	-0.025	0.061
	CTZ	135	0.013	0.012	0.006	0.013	0.020	-0.016	0.064
	BTP 10 ind	72	0.055	0.066	0.031	0.047	0.090	-0.179	0.244

Table C.31 – Correlation Coefficients on-the-run (weekly freq – yields)

		BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
quote freq	*BTP 30*	1					
	BTP 10	0.3288*	1				
	BTP 5	0.1902	0.1711*	1			
	BTP 3	0.2671*	0.3479*	0.3114*	1		
	CTZ	0.0129	0.1377	0.2211*	0.1989*	1	
	BTP 10 ind	0.4767*	-0.0586	0.1345	-0.0032	0.0121	1
weigh spread	*BTP 30*	1					
	BTP 10	0.4504*	1				
	BTP 5	0.4008*	0.4959*	1			
	BTP 3	0.2537*	0.3116*	0.5213*	1		
	CTZ	-0.3605*	0.0623	-0.2994*	-0.0923	1	
	BTP 10 ind	0.2092	0.3302*	0.068	0.0634	0.2213*	1
second size	*BTP 30*	1					
	BTP 10	0.1818	1				
	BTP 5	0.3049*	0.4819*	1			
	BTP 3	0.3651*	0.6371*	0.4628*	1		
	CTZ	0.3080*	0.4349*	0.2658*	0.4469*	1	
	BTP 10 ind	0.2094*	0.028	0.0324	0.0156	0.3137*	1
worst size	*BTP 30*	1					
	BTP 10	0.013	1				
	BTP 5	0.1218	-0.0057	1			
	BTP 3	0.2672*	-0.0447	0.3872*	1		
	CTZ	0.3648*	-0.0829	0.2260*	0.1309	1	
	BTP 10 ind	0.5192*	0.0361	0.0726	0.1084	0.3523*	1
quote size	*BTP 30*	1					
	BTP 10	0.2424*	1				
	BTP 5	0.4280*	0.4413*	1			
	BTP 3	0.5263*	0.5451*	0.5756*	1		
	CTZ	0.5070*	0.2875*	0.2887*	0.4746*	1	
	BTP 10 ind	0.4945*	0.3499*	0.3634*	0.5474*	0.4700*	1
quote size per partic.	*BTP 30*	1					
	BTP 10	0.1296	1				
	BTP 5	-0.1697	-0.0266	1			
	BTP 3	-0.0299	0.1928*	0.069	1		
	CTZ	0.2351*	-0.0228	-0.167	0.1076	1	
	BTP 10 ind	0.1311	0.0393	-0.0668	0.0286	0.09	1
slope	*BTP 30*	1					
	BTP 10	-0.0244	1				
	BTP 5	-0.0248	0.2319*	1			
	BTP 3	-0.0292	0.2554*	0.2793*	1		
	CTZ	-0.0904	0.1786*	0.0513	0.1357	1	
	BTP 10 ind	-0.0999	0.1989	0.0689	0.2027	0.0204	1
DSS	*BTP 30*	1					
	BTP 10	0.0325	1				
	BTP 5	0.0049	-0.0429	1			
	BTP 3	-0.0432	0.1111	-0.1055	1		
	CTZ	-0.0606	-0.1018	-0.0887	0.0877	1	
	BTP 10 ind	-0.059	0.0364	-0.0293	-0.0534	-0.097	1

Table C.32 – Correlation Coefficients on-the-run (weekly freq – yields) [2]

		BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
trade size	*BTP 30*	1					
	BTP 10	0.0469	1				
	BTP 5	0.0816	0.0331	1			
	BTP 3	0.0066	0.2766*	0.1699	1		
	CTZ	0.0405	-0.0491	-0.0623	-0.0983	1	
	BTP 10 ind	-0.0236	0.0973	-0.1237	-0.2102*	-0.0549	1
trade freq	*BTP 30*	1					
	BTP 10	0.1205	1				
	BTP 5	0.1137	0.0758	1			
	BTP 3	0.0348	0.1678*	0.3083*	1		
	CTZ	-0.0155	0.0831	-0.003	0.1689*	1	
	BTP 10 ind	-0.0221	-0.033	0.1206	0.0522	0.055	1
turnover	*BTP 30*	1					
	BTP 10	0.0398	1				
	BTP 5	-0.0374	0.0439	1			
	BTP 3	0.0002	0.0273	0.1177	1		
	CTZ	0.0298	-0.0478	-0.0556	0.0186	1	
	BTP 10 ind	-0.1732	-0.2220*	0.0221	0.0594	-0.0356	1

Table C.33 – Price Impact Regressions (prices) [1]

BTP 10 - on-the-run

	mod1	mod2	mod3	mod4
NTC	.00179633***		.00300138***	
NTQ		.00023451***	-.00017471**	
#buy				.00161982***
#sell				-.00198601***
_cons	-0.00013147	-0.00006703	-0.00016684	0.00023332
N	16493	16493	16493	16493
Adj R^2	0.0253	0.0218	0.0259	0.0254

BTP 10 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00242393***		.00525041***	
NTQ		.00029266***	-.0003819***	
#buy				.00237672***
#sell				-.00247228***
_cons	-.00082145***	-.00079843***	-.00084869***	-.00073654*
N	14787	14787	14787	14787
Adj R^2	0.0400	0.0335	0.0427	0.0399

BTP 5- on-the-run

	mod1	mod2	mod3	mod4
NTC	.00165581***		.00023421***	
NTQ		.00023421***	-0.00006379	
#buy				.00137219***
#sell				-.00196541***
_cons	-0.0002	-0.0001	-0.0002	0.0003
N	9110	9110	9110	9110
Adj R^2	0.0393	0.0335	0.0394	0.0401

BTP 5 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00114556***		.00199149***	
NTQ		.00014448***	-0.00012161	
#buy				.00139657***
#sell				-.00093947***
_cons	-0.0001	-0.0001	-0.0001	-0.0004
N	4795	4795	4795	4795
Adj R^2	0.0179	0.0148	0.0184	0.0180

BTP 3- on-the-run

	mod1	mod2	mod3	mod4
NTC	.00115837***		.00151003***	
NTQ		.00013797***	-0.00004927**	
#buy				.00101619***
#sell				-.00132328***
_cons	-0.00002	0.00004	-0.00004	0.00025
N	12307	12307	12307	12307
Adj R^2	0.0593	0.0484	0.0599	0.0599

BTP 3 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00104192***		.0011513***	
NTQ		.00012656***	-0.00001445	
#buy				.00107926***
#sell				-.00100637***
_cons	0.00002	0.00005	0.00002	-0.00004
N	5891	5891	5891	5891
Adj R^2	0.0607	0.0553	0.0606	0.0606

Table C.34 – Price Impact Regressions (prices) [2]

BTP 30- on-the-run

	mod1	mod2	mod3	mod4
NTC	.00645885***		.01177103***	
NTQ		.00147575***	-.00141641**	
#buy				.00470947***
#sell				-.00844888***
_cons	-.00188333*	-.00178245*	-.0019427*	0.0014
N	3527	3527	3527	3527
Adj R^2	0.0617	0.0491	0.0650	0.0649

BTP 30 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00573779***		.00658227*	
NTQ		.00140584***	-0.00022281	
#buy				.00557165***
#sell				-.00587237***
_cons	-.00337155*	-.0034665*	-.00337076*	-0.0031
N	1611	1611	1611	1611
Adj R^2	0.0461	0.0423	0.0455	0.0455

CTZ- on-the-run

	mod1	mod2	mod3	mod4
NTC	.00051526***		.00064672***	
NTQ		.00007902***	-.00003076***	
#buy				.00052232***
#sell				-.00050882***
_cons	-0.00007	-0.00007	-0.00007	-0.00008
N	14826	14826	14826	14826
Adj R^2	0.0370	0.0219	0.0379	0.0370

CTZ - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00034797***		.00043129***	
NTQ		.00005876***	-.00002016**	
#buy				.00035287***
#sell				-.00034342***
_cons	0.00004	0.00004	0.00004	0.00004
N	8072	8072	8072	8072
Adj R^2	0.0476	0.0306	0.0484	0.0475

BTP10ind on-the-run

	mod1	mod2	mod3	mod4
NTC	.00740692***		.00590956***	
NTQ		.00101923***	0.00022742	
#buy				.00763031***
#sell				-.00712548***
_cons	-.00193335*	-.00185117*	-.00193321*	-0.00239
N	1682	1682	1682	1682
Adj R^2	0.1969	0.1831	0.1975	0.1965

BTP10ind on-the-run

	mod1	mod2	mod3	mod4
NTC	.00498437***		.00431069*	
NTQ		.00074193***	0.00010938	
#buy				.00356282**
#sell				-.00593681***
_cons	-0.00245	-.00307077*	-0.00251	-0.00037
N	390	390	390	390
Adj R^2	0.1285	0.1193	0.1265	0.1295

Table C.35 – Price Impact Regressions (yields) [1]

BTP 10 - on-the-run

	mod1	mod2	mod4
NTC	.00556687***		
NTQ		.00073205***	
#buy			.00502615***
#sell			-.00614619***
_cons	-0.0002911	-0.00010347	0.00082848
N	15600	15600	15600
Adj R^2	0.0253	0.0222	0.0255

BTP 10 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00827773***		.01736769***	
NTQ		.00100229***	-.00122471***	
#buy				.00822709***
#sell				-.00833062***
_cons	-.00278909***	-.00271521***	-.00286959***	-.00269682*
N	13720	13720	13720	13720
Adj R^2	0.0381	0.0323	0.0403	0.0380

BTP 5- on-the-run

	mod1	mod2	mod4
NTC	.01211389***		
NTQ		.00170493***	
#buy			.01009039***
#sell			-.01458467***
_cons	-0.0015	-0.0006	0.0024
N	8792	8792	8792
Adj R^2	0.0390	0.0335	0.0398

BTP 5 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.01015879***		.01708408***	
NTQ		.00128409***	-0.00099393	
#buy				.01245334***
#sell				-.00830205***
_cons	-0.0006	-0.0004	-0.0008	-0.0037
N	4432	4432	4432	4432
Adj R^2	0.0183	0.0152	0.0187	0.0185

BTP 3- on-the-run

	mod1	mod2	mod4
NTC	.01545527***		
NTQ		.00182774***	
#buy			.01345838***
#sell			-.01783078***
_cons	0.00024	0.00112	.00411767*
N	11745	11745	11745
Adj R^2	0.0580	0.0471	0.0586

BTP 3 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.01711192***		.01953793***	
NTQ		.00207247***	-0.00032051	
#buy				.01762377***
#sell				-.01662439***
_cons	0.00045	0.00085	0.00038	-0.00038
N	5891	5891	5891	5891
Adj R^2	0.0618	0.0560	0.0617	0.0616

Table C.36 – Price Impact Regressions (yields)

[2]

BTP 30- on-the-run

	mod1	mod2	mod4
NTC	.00929107***		
NTQ		.00212223***	
#buy			.00681039***
#sell			-.012113***
_cons	-.00277424*	-.00262903*	0.0019
N	3527	3527	3527
Adj R^2	0.0613	0.0488	0.0644

BTP 30 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00878009***		.01115693**	
NTQ		.00213565***	-0.00062768	
#buy				.00839777***
#sell				-.00909075***
_cons	-.0053145*	-.00543772*	-.00531986*	-0.0047
N	1543	1543	1543	1543
Adj R^2	0.0452	0.0408	0.0448	0.0446

CTZ- on-the-run

	mod1	mod2	mod4
NTC	.01080011***		
NTQ		.00164825***	
#buy			.01103121***
#sell			-.01059124***
_cons	-0.00093	-0.00097	-0.00136
N	14542	14542	14542
Adj R^2	0.0387	0.0227	0.0386

CTZ - off-the-run

	mod1	mod2	mod3	mod4
NTC	.01126714***		.01289487***	
NTQ		.0019654***	-0.00039378	
#buy				.01145072***
#sell				-.01109639***
_cons	0.00132	0.00131	0.00133	0.00099
N	8065	8065	8065	8065
Adj R^2	0.0534	0.0367	0.0536	0.0533

BTP10ind on-the-run

	mod1	mod2	mod4
NTC	.05511498***		
NTQ		.00745932***	
#buy			.05081192***
#sell			-.05987435***
_cons	-.01929499**	-.01722019*	-0.01106
N	1301	1301	1301
Adj R^2	0.1988	0.1761	0.1989

BTP10ind on-the-run

	mod1	mod2	mod3	mod4
NTC	.03867193***		.03309337*	
NTQ		.00576182***	0.00090572	
#buy				.02791238**
#sell				-.04588085***
_cons	-0.01789	-.02269709*	-0.01836	-0.00213
N	390	390	390	390
Adj R^2	0.1308	0.1217	0.1288	0.1317