Financial Market Behavior during the European Sovereign Debt Crisis

A MARKET MICROSTRUCTURE APPROACH

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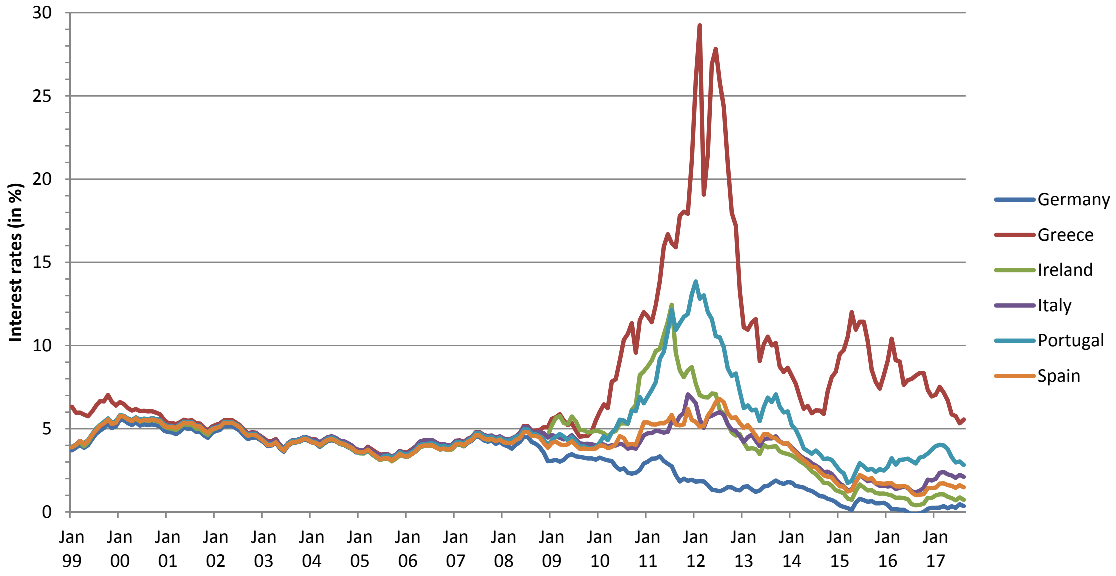
1 Introduction

After the demise of Lehman Brothers in autumn 2008, the financial crisis spread extensively to Europe. It was notably followed by a deceleration in economic activity in 2009, with negative growth rates that were the largest in many countries since the Great Depression in the 1930s. The third stage of the crisis began early in 2010 when Greece—later followed by Ireland, Portugal, Italy, Spain and more recently Slovenia and Cyprus—came under pressure from a strong increase in sovereign debt, a persistent instability of their financial sectors, bursting housing bubbles and a further slowdown in economic activity. Beginning in late 2009, investors responded by demanding higher yields on Greek debt securities and gradually began driving up yields on sovereign bonds of other eurozone member states. As a consequence, these countries' governments became temporarily unable to cover their financial needs by issuing bonds at "affordable" interest rates, which in many cases made loan agreements by European countries, the International Monetary Fund and newly-established special purpose vehicles necessary. Since then, capital markets have calmed down not because European economies have engaged in austerity, but because the European Central Bank is intervening by purchasing sovereign bonds in the secondary market and has promised to do "whatever it takes to preserve the euro".

The European sovereign debt crisis has revived the debate of policymakers and academics on the determinants and dynamics of market liquidity.[1] While liquid financial markets have long been taken for granted, the crisis has shown that a sudden shortage can easily occur. The present dissertation contributes to the debate on

[1] Valuable reviews of current liquidity dynamics are provided by Committee on the Global Financial System (2016b), European Systemic Risk Board (2016) and European Supervisory Authorities (2017), among others.



Source: European Central Bank (2017c)

Figure 1.1: Secondary market yields of sovereign bonds with maturities of close to ten years (1999-2017)

market liquidity during the European sovereign debt crisis. In particular, it provides new evidence on market-making activities in sovereign bond trading and outlines a number of policy implications that, if pursued, may support market liquidity in Europe's fixed-income markets.

Chapter 2, entitled **Characterization of European sovereign bond markets**, introduces the asset class of sovereign bonds. Even if European national treasuries have made an effort to harmonize the design of their debt obligations in recent decades, differences in terms, structures, requirements and other details remain. To better understand the peculiarities and similarities, we give an introduction to the terminology of bonds and present some stylized facts of European government debt obligations. In the further course of the chapter, we discuss organizational features of issuing new debt on Europe's primary markets. We work out issuance strategies and methods as well as associated factors of debt management, risk control, investor base and investor relationships. Additionally, we introduce types of negotiations, trading mechanisms, roles for dealers and intermediaries, competition among investors and the level of market transparency in secondary bond markets. Finally, we present stylized facts of the largest electronic interdealer platform for trading euro-denominated sovereign bonds, MTS. These insights lay the foundation for the empirical investigations in the further course of this thesis.

Due to the bulk of sovereign debt obligations in circulation, many bond markets are characterized by temporary imbalances in the inflow of buy and sell orders. To ensure continuous trading opportunities, selected market participants serve a crucial role in these markets by posting executable bid and offer prices. Recent developments suggest that the behavior of these liquidity providers may have changed during the crisis. Against this background, Chapter 3, entitled **Insights from market microstructure theory on dealer markets**, focuses on the theoretical analysis of market-making activities of liquidity suppliers and its implications for the price discovery process in dealer markets. We follow the evolution of the theoretical literature on market microstructure and discuss firstly the three "traditional" sources of trading costs a dealer is typically confronted with; namely order processing costs, inventory holding costs and costs due to information asymmetries in the market. Since most of today's trading in European sovereign bonds is characterized by a multiple dealer structure, we turn our attention later to a competitive market-making framework and study the role of interdealer trading on the price formation process. The chapter closes with a summary of empirically testable price implications.

Chapter 4, entitled **Decomposition of bid-ask spreads in European fixed-income markets**, examines the determinants and dynamics of liquidity in European fixed-income markets during the sovereign debt crisis. We recapitulate the market microstructure framework of Huang and Stoll (1997) and extend their spread decomposition model to capture intrinsic features of bond trading: interdealer inventory trading, order splitting, market-wide and country-specific trends, term-to-maturity effects as well as weekday and intraday patterns. Using high-frequency quote and trade data from the largest electronic interdealer platform for trading euro-denominated fixed-income securities, MTS, we find that trading on private information is rather less important in sovereign bond markets. Dealers only request compensation at the beginning of the trading week and the trading day when trading activity is fairly low and information asymmetries likely. Due to the local competitor, EUREX, and parallel price discovery processes, insider trading is relevant in the market for German bonds. Inventory control only plays a marginal role in dealers' decision of setting the bid-ask spread. It seems to be more likely that dealers actively trade and hedge imbalances. Market-wide trends in buying or selling are as important as the two traditional asset-specific spread components combined.

Chapter 4 leaves open the question of whether other factors may influence the price-setting behavior of liquidity providers in Europe's bond markets or not. Against this background, Chapter 5, entitled **The influence of political communication on the price discovery process in sovereign bond markets**, aims to shed light on the signaling effects of political communication on sovereign bond trading in times of financial crisis. Our data sample covers high-frequency quote and trade data of more than 500 euro-denominated sovereign bonds for the period between January 2 and June 28, 2013, when the bailout of Cyprus caused heated debates on bank deposit levies and bail-in procedures. Within the framework of a market microstructure approach, we find press conferences, speeches, interviews and written statements of political actors to have demonstrable effects on the quoting behavior of institutional investors. Communications on attempts to break the sovereign-bank nexus have a coordinating and soothing effect, while discussions on Cyprus' role as a template for future rescue measures trouble the markets. However, the impact holds for a maximum of 30 minutes and largely depends on the originator of the statement. We conclude that in times of market uncertainty, public signals can be an important source for investment decisions in sovereign bond markets. To have a lasting effect, however, a coherent communication strategy is necessary.

Chapter 6, entitled **Did the EU summits succeed in convincing the markets during the recent crisis?**, slightly changes our perspective. We analyze the price impact of European Council meetings on Europe's financial markets during the peak of the sovereign debt crises. Therewith, we follow our present argumentation that public information may be an important signaling device in times of economic and financial crisis. However, we zoom out of the tight analysis of market-making activities in secondary bond market trading and also expand the focus to equity and forex markets. Using an event study approach, this chapter examines whether crisis meetings of European heads of state and government, as well as their agreed and communicated results, had a significant impact on financial markets. The analysis is based on daily data for seven member states of the eurozone (France, Germany, Greece, Ireland, Italy, Portugal and Spain), starting in autumn 2008 and covering the time period until April 2012. We find the high-profile meetings to have only minor effects that ceased quickly. Only Germany was able to profit from sustainably better market conditions after meetings. As opposed to this, first and foremost Greece faced partly severe negative effects. We conclude that investors consider Europe's economic and political crisis management insufficient and its communication strategy little convincing. While controlling for additional effects, we show that conventional and unconventional policy measures taken by the ECB have had short-run effects on bond returns and the exchange rate, but none of the intended influence on stock prices, with the exception of Italy. The article, on which this chapter is based, is co-authored by Prof. Dr. Heinz-Dieter Smeets and has been published in *Journal of Common Market Studies, Vol. 51, No. 6, November 2013, pp. 1158–1177.*

2 Characterization of European sovereign bond markets

Abstract

In the wake of the global financial crisis, some eurozone countries came under severe pressure from a slowdown in economic activity, persistent instability of their financial sectors and high public expenditures. Liquidity and credit risk concerns in the market led to a sharp spike in sovereign bond yields of Greece, Ireland, Italy, Portugal, Spain and Cyprus. Some of them lost access to capital markets and were, at least temporarily, unable to cover their financial needs by issuing bonds at "affordable" interest rates. Against this background, the present chapter delivers a comprehensive overview of the asset class of sovereign bonds, its characteristics and risks as well as organizational features of European primary and secondary bond markets. These insights lay the foundation for the empirical investigations in the further course of this thesis.

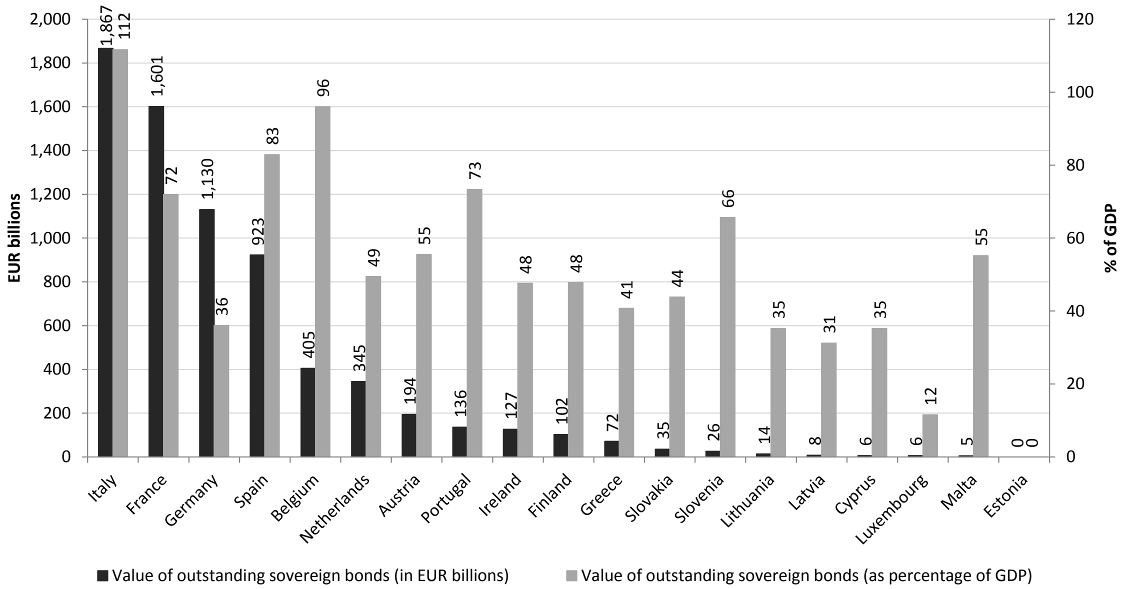
2.1 Introduction

Sovereign bonds are debt securities issued by the central government of a country. Governments issue bonds to finance general and specific budget expenditure or to refinance existing debts. In principle, bonds work similarly to a loan from a bank. However, it is not one financial institution but many investors in a public market—which nevertheless most often are banks—who loan capital to the government. They do so for a defined period of time and under the presumption of receiving interest payments at a predetermined rate and schedule. Once the debt obligation comes due, the debtholders receive back the face value of the loaned funds from the issuing entity.

Sovereign bonds serve further important purposes. They are used by central banks to conduct open market operations for the management of liquidity and interest rates in the financial system. Besides its role as a policy tool, sovereign bonds indicate the risk-free rate in the country and serve as benchmarks in pricing corporate debt. From a portfolio management perspective, sovereign bonds represent an important asset class that allows money managers to balance portfolios and hedge risks.

With an outstanding aggregate value of about EUR 9,758.2 billion at the end of 2016, the sovereign bond market of the European Union is the world's largest market for debt securities (EU Economic and Financial Committee, 2017). The 19 central governments of the eurozone accounted for an aggregate value of EUR 7,002.3 billion. Table 2.1 provides an overview of the outstanding values by issuing country. For years, the largest European issuer has been the Italian Treasury, with an outstanding value of EUR 1,867.2 billion, followed by France (EUR 1,601.2 billion) and Germany (EUR 1,130.0 billion). Concerning the ratio of the outstanding value of sovereign bonds and national GDP, at the end of 2016, Italian central government bonds in circulation were worth 112 percent the size of its national economy. Italy is followed by Belgium (96 percent), Spain (83 percent) and Portugal (73 percent). The reporting is different to the conventional general government debt-to-GDP ratio, which subsumes all liabilities (currency and deposits, debt securities and loans) of the central government, state government, local government and social security funds. This is the reason why outstanding sovereign bonds of Greece account only for 41 percent of national GDP, while Greece leads the debt-to-GDP statistic with 179 percent.

The remainder of this chapter is organized as follows: Sections 2.2 and 2.3 introduce the asset class of sovereign bonds and associated investment risks. Section 2.4 presents differences and similarities in issuance procedures in European primary markets. Important organizational features of secondary bond market trading are discussed in Section 2.5. Section 2.6 focuses on the peculiarities of the largest and most important interdealer market for trading euro-denominated sovereign bonds. Finally, Section 2.7 summarizes the most important findings and therewith lays the foundation for the following chapters.



Sources: EU Economic and Financial Committee (2017), Eurostat (2017)

Figure 2.1: Central government debt securities outstanding (end-2016, EA-19)

2.2 Basics of sovereign bonds

The asset class of sovereign bonds is highly heterogeneous. Even if European national treasuries have made an effort to harmonize their debt obligations over the course of last decades, differences in terms, structures, requirements and other details remain. To better understand the differences and similarities, this section gives an introduction to the terminology of bonds and presents some stylized facts of European government debt obligations.

2.2.1 Principal value of a bond

The principal of a bond, also known as par value or face value, is the amount of money a creditor is lending to the issuer at the beginning of a bond's lifetime. It is the same amount of money the issuer has to pay back once the bond matures. Bonds are often referred to as fixed-income securities because creditors know the exact amount of cash they will get back if they hold the security until maturity. The principal is not the price of the security. The price is determined in the market and may fluctuate over time, while the principal is constant over the life of a bond. When a bond is traded at a price above par, it is said to be traded at a premium. When a bond is traded below par, it is traded at a discount.

2.2.2 Different types of coupon payments

An important feature of bonds is the coupon rate or nominal yield. For the privilege of using a creditor's money, the issuer makes predetermined and scheduled interest payments on the face value of the bond. Sovereign bonds typically pay interest on fixed coupon dates. Common intervals are months, quarters, half-years or years. Bonds with predetermined fixed remuneration rates of their face value are called fixed-rate bonds, conventional bonds, nominal bonds or "plain vanilla" bonds.

Even if fixed-rate bonds are the most common type of government debt obligations, other forms of contracts are in use as well. Zero-coupon or discount bonds do not pay any regular coupon payments over a bond's lifetime. Instead they are issued at a discount to face value. This type of bond is often used for short-term securities. Another possibility is an adjustable interest payment, known as a floating-rate bond. It is common in sovereign bond markets to tie interest rates to inflation, which is why these bonds are often known as inflation-linked bonds or linkers, or to tie interest rates on a benchmark rate such as EURIBOR plus some additional "spread". Even if special redemption features like call or put options are not very common for sovereign bonds, we will shortly explain the underlying idea. A call option allows the issuer to call back the bond from its debtholders before maturity. This is useful when market interest rates drop and it becomes cheaper for the issuer to issue new bonds at a lower coupon rate. Due to the creditor's risk of giving back the bond before maturity, callable bonds are typically traded at a premium to regular debt obligations. On the other hand, putable bonds are those that allow creditors to put them back at specified times prior to maturity. This can be useful when cash is needed or market interest rates rise and alternative investments become more attractive. Finally, some governments, like France or Italy, offer so-called stripped bonds, which are bonds stripped into the principal repayment and coupon payments and which are sold individually. Table 2.1 summarizes the predominant coupon types in use by the eurozone governments.

Table 2.1: Sovereign bond issues by coupon type (2016, EA-19)

	Bills 1Y-	Notes 1-10Y	Bonds 10Y+
Austria	Z	F	F
Belgium	O	F/FL	F
Cyprus	F	F	
Estonia			
Finland			
France	O	F/IL	F/IL
Germany	Z	F/IL	F/IL
Greece	F		
Ireland	Z	F	F
Italy	Z	Z/F/IL/FL	F/IL
Latvia	F	F	F
Lithuania		F	F
Luxembourg			
Malta		F	F
Netherlands	Z	F	F
Portugal	Z	F/FL	F
Slovakia	F	Z/F	F
Slovenia	F	F	
Spain	Z	F/IL	F/IL

Notes: F - fixed-rate, FL - float, IL - index-linked, Z - zero-coupons, O - other
Source: EU Economic and Financial Committee (2017)

2.2.3 Distinction by maturity

Sovereign bonds can further be classified by their maturity, i.e. the future date on which the issuer is paying back the principal. Even if in practice the words maturity, duration, term and term-to-maturity are used interchangeably, technically there are differences. While maturity refers to the date the debt will cease and the bond will be redeemed, the other terminologies denote the time interval until maturity.

Term-to-maturities can range from a few days to more than 30 years. Even though the variety of bond classification according to maturity is large, there are three main categories of fixed-income securities. Sovereign bonds with a duration of less than one year are referred to as “bills”. They are also called money market papers or treasury discount papers and are used to meet short-term financing needs. Bills are often issued at a discount from face value instead of payment of coupon interests. “Notes” are medium-term debt securities maturing in one to 10 years. Sometimes a distinction is made between short-term notes of up to five years and medium-term notes with maturities of five to 10 years. They represent the middle of the yield curve and have a higher price risk in comparison to bills. Finally, “bonds” represent the long end of the yield curve with durations of more than 10 years. In most cases, notes and bonds make interest payments periodically. Table 2.2 shows the total gross issuance of sovereign bonds by the 19 eurozone countries in 2016. It further shows the percentage shares of bills, notes and bonds issued. The shares largely depend on country-specific financing needs and represent a snapshot in time. Greece, for instance, still has limited access to capital markets and was only able to issue short-term debt obligations in 2016.

Table 2.2: Sovereign bond issues by term-to-maturity (2016, EA-19)

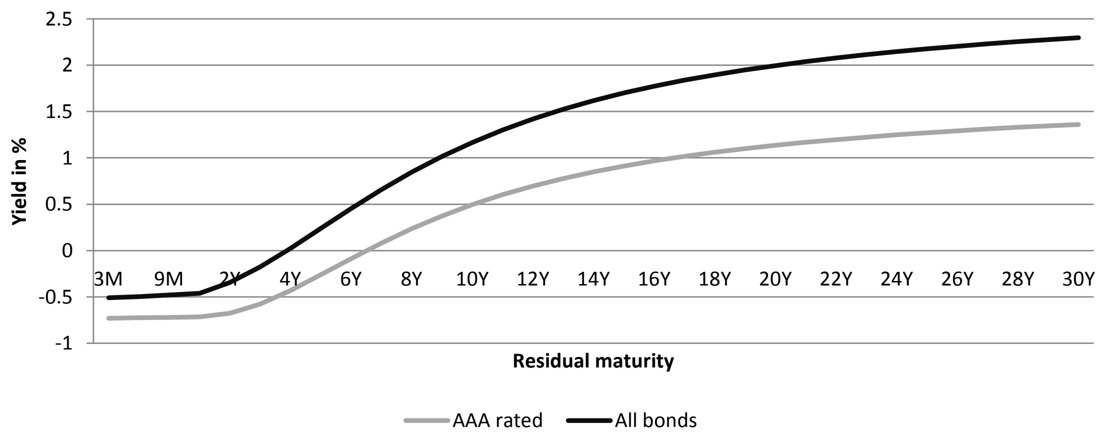
	Total gross issuance (in EUR millions)	Percentage values of issued bonds by duration			Total net issuance (in EUR millions)
		Bills 1Y-	Notes 1-10Y	Bonds 10Y+	
Austria	27,491	20.2	55.6	40.9	8,970
Belgium	86,366	56.4	22.1	21.5	13
Cyprus	2,726	52.4	47.6	0.0	1,597
Estonia	0	0.0	0.0	0.0	
Finland	17,174	20.3	47.7	32.0	2,536
France	538,998	60.2	32.3	7.7	45,092
Germany	201,154	20.7	73.8	5.5	-3,927
Greece	40,998	100.0	0.0	0.0	-3,117
Ireland	10,504	19.1	72.6	8.3	-2,333
Italy	408,486	37.4	49.6	14.3	56,450
Latvia	1,898	17.1	48.6	34.2	1,245
Lithuania	1,341	0.0	66.4	33.6	-97
Luxembourg	0	0.0	0.0	0.0	
Malta	1,570	61.9	4.1	34.0	213
Netherlands	79,977	66.7	28.9	4.4	3,892
Portugal	36,758	41.2	54.4	4.5	11,429
Slovakia	5,446	7.3	50.4	42.3	673
Slovenia	5,273	5.8	16.0	78.2	1,788
Spain	221,613	45.6	41.1	15.2	35,043

Source: EU Economic and Financial Committee (2017)

The term-to-maturity of a bond is crucial for several reasons. First, it indicates the number of periods during which a bondholder can expect to receive coupon interest payments and the number of days, months or years before the principal will be paid back. Second, term-to-maturity influences the volatility of a bond. Interest rate changes have a larger impact on the market price of long-term bonds than on the price of debt obligations with a shorter lifespan. Long-term securities are also more vulnerable to other market risks like inflation or the risk of default. Third, term-to-maturity is correlated to market liquidity. For several reasons, like the share of investors with a buy-and-hold strategy, markets for long-term bonds tend to be less liquid in comparison to trading short-term bonds. Finally, term-to-maturity determines the yield on a bond. The relationship depends on the shape of the yield curve.

2.2.4 The pattern of yield curves

The yield of a bond shows its current return in the secondary market for trading bonds. In its simplest version, the yield is calculated as the product of a bond's principal and its coupon rate divided by the actual price in the market. If the price corresponds to the face value, yield and coupon rates are the same. However, if the demand for a particular bond is high and the price goes up, the yield shrinks, and vice versa. A more accurate measure—especially to compare bonds with different maturities and coupons—is the yield-to-maturity. It includes all interest payments up until maturity plus the capital gains if the bond is purchased below par or capital losses if it is purchased above par. The yield-to-call measure is calculated the same way but it is assumed that interest payments will be paid until call date. Independent of the calculation method used, higher yields for in other respects similar bonds reflect differences in investors' evaluation of credit risk.



Source: European Central Bank (2017b)

Figure 2.2: Yield curves of AAA-rated euro area central government bonds and of all euro area central government bonds as of May 9, 2017

Maturity and yield are interrelated. The normal relationship is that the longer the term-to-maturity, the higher the yield. The reason for this is the potential risk of unfavorable price fluctuations for which investors expect to be compensated. Figure 2.2 presents the aggregated yield curve of member states of the eurozone with the highest credit rating (AAA) and the aggregated yield curve of all 19 eurozone countries. Both curves show a typical pattern with a fairly steep rise in yields between short-term and medium-term bonds and a less pronounced rise between medium-term and long-term securities. Figure 2.3 shows three variations from the normal pattern. If the yield curve is "steep", the yields on short-term bonds are relatively low when compared to long-term bonds, which makes buying bonds with a longer term-to-maturity relatively more attractive. A steep yield curve typically indicates market expectations for rising inflation and/or stronger economic growth. If the yield curve is "flat", the difference between short-term and long-term yields is relatively small and there is no large incentive to invest in long-term bonds. A flattening yield curve can indicate that investor expectations for future inflation are falling. When inflation is less of a concern, investors accept lower long-term rates because they do not expect that inflation will significantly reduce the future value of their investment. If the yield curve is "inverted", yields on short-term issues are higher than those on long-term issues. An inverted yield curve is considered to be a predictor of economic recession. Investors tolerate low rates because they expect rates are going to fall even lower later on.

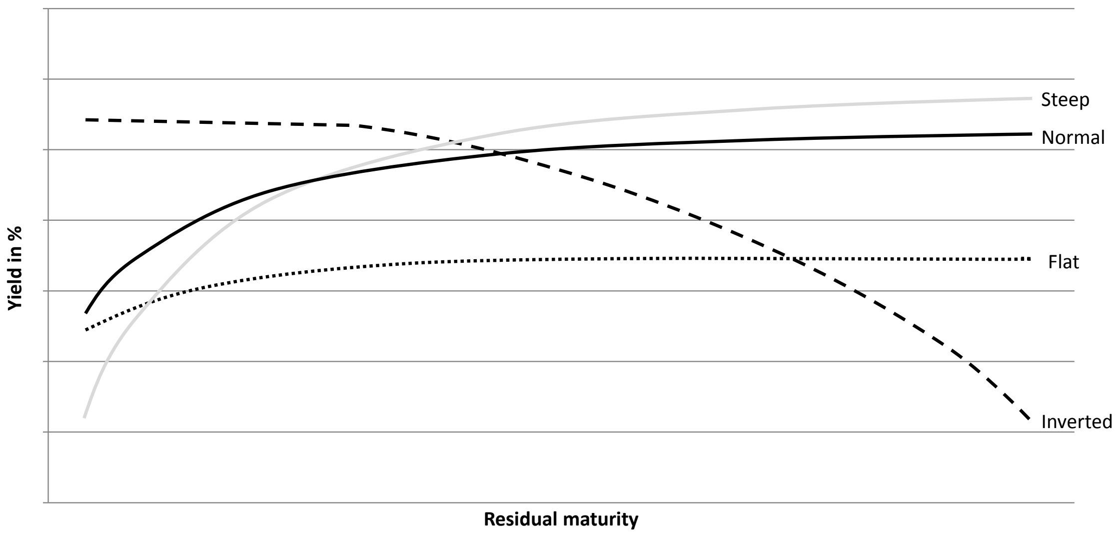


Figure 2.3: Yield curve variations

2.3 Risks of investing in sovereign bonds

Sovereign bonds are widely considered to be a safe investment. However, there are potential risks of holding bonds, which will be exposed in this section.

2.3.1 Credit risk

The European sovereign debt crisis has shown that even sovereign bonds of developed countries carry some level of credit risk. The issuing government may either be unable to render the contractual interest payments in a timely manner or to default (at least partly) on the principal. Credit risk is therefore often referred to as issuer risk or default risk.

To assess the credit risk of a bond and the issuing entity, some specialized agencies calculate credit ratings. In the case of sovereign bonds, these ratings are based on fundamental values of the economy and the government's ability to meet its obligations. A rating shows a credit rating agency's opinion on how likely it is that a default will occur. The agencies stress that their ratings are opinions and not investment recommendations. However, during the European sovereign debt crisis, they were criticized because of their role in shaping market perceptions. U.S.-based Standard & Poor's, Moody's and Fitch are the three largest credit rating agencies in the world. All of them have their own bond rating system, which differs in the method of calculation and scale. However, as Table A.1 shows, the rating scales of the three agencies can be divided into the same categories from highest credit quality to default. If a country falls below a certain credit rating, the grade of its debt obligations changes from investment quality to junk status. Ratings are reviewed periodically and may be upgraded, downgraded or left unchanged.

A list of the sovereign ratings of eurozone member states as of May 2017 is provided in Table 2.3. Most European countries are considered to be virtually free from credit risk and their bonds are rated as medium grade investments up to prime grade investments. As of May 2017, Germany, Luxembourg and the Netherlands are assessed as extremely unlikely to default on their bonds. According to the three rating agencies, sovereign bonds of Cyprus, Portugal and Greece are classified as "speculative", "highly speculative" and even "extremely speculative". For different reasons, all three countries as well as Ireland, Spain and to a lesser extent, Italy came under severe pressure in the wake of the global financial crisis. High payment obligations led the credit risk rise which resulted in rating downgrades. Since credit ratings are an important benchmark for most investors, it became more difficult for these countries to issue new bonds at affordable interest rates. Due to this restricted market access, financial assistance by the other eurozone member states became necessary. The rescue packages from the temporary rescue fund, European Financial Stability Facility, and later the permanent rescue fund, European Stability Mechanism, have played the key role in servicing these countries' financial needs and overcoming structural weaknesses of their economies. In 2017, most of the eurozone crisis countries have restored investors' trust and have returned to normal market access.

Table 2.3: Long-term sovereign ratings as of May 2017 (EA-19)

	S&P		**Moody's**		**Fitch**	
	Rating	Outlook	Rating	Outlook	Rating	Outlook
Germany	AAA	Stable	Aaa	Stable	AAA	Stable
Luxembourg	AAA	Stable	Aaa	Stable	AAA	Stable
Netherlands	AAA	Stable	Aaa	Stable	AAA	Stable
Austria	AA+	Stable	Aa1	Stable	AA+	Stable
Finland	AA+	Stable	Aa1	Stable	AA+	Stable
France	AA	Stable	Aa2	Stable	AA	Stable
Belgium	AA	Stable	Aa3	Stable	AA	Stable
Estonia	AA-	Stable	A1	Stable	A+	Stable
Slovakia	A+	Stable	A2	Stable	A+	Stable
Ireland	A+	Stable	A3	Positive	A-	Stable
Slovenia	A	Positive	Baa3	Stable	A-	Stable
Malta	A-	Stable	A3	Stable	A+	Stable
Latvia	A-	Stable	A3	Stable	A-	Stable
Lithuania	A-	Stable	A3	Stable	A-	Stable
Spain	BBB+	Positive	Baa2	Positive	BBB+	Stable
Italy	BBB-	Stable	Baa2	Stable	BBB+	Stable
Portugal	BB+	Stable	Ba1	Stable	BB+	Positive
Cyprus	BB+	Stable	B1	Positive	BB-	Positive
Greece	B-	Stable	Caa3	Stable	CCC	Negative

Sources: Standard & Poor's (2017a), Moody's (2017b), Fitch Ratings (2017b)

2.3.2 Market risk

A good part of the sovereign bond market is buy and hold. Once a bond is purchased, it is never traded again but simply redeemed at maturity. For investors who follow a buy-and-hold strategy, interest rate risk on market value is a minor factor. Investors receive the full principal value at maturity, regardless of any short-term changes in market value. However, other investors decide or are obligated to trade bonds in the so-called secondary market. The market price of a bond may then fluctuate depending on demand and supply conditions. When the bond has a coupon similar to prevailing interest rates, the bondholder would, ceteris paribus, be indifferent to purchasing the security or saving his money at the current interest rate. However, if prevailing interest rates rise above the coupon, holding the security is no longer an attractive option. Newer bonds with higher coupon rates decrease the demand for older bonds that pay lower interest. The decreased demand depresses the bond price of older bonds in the secondary market. Bondholders who need to sell the bond have to do so at a discount. They have to sell their bonds below par until the effective rate equals market interest rates. Conversely, if interest rates drop below the coupon, holding the bond becomes a more attractive option. Market demand increases. Investors purchase the security, bidding the price up until the effective rate on the bond equals market interest rates.

2.3.3 Inflation risk

Inflation risk or purchasing power risk refers to the risk that price increases in the economy deteriorate a bond's return. Inflation risk is relevant especially for fixed-rate bonds where an environment of high interest rates and inflation erodes the relative value of investments. In contrast, the interest rate and principal of floating-rate bonds is adjusted periodically to match inflation rates. This limits the risk of losing purchasing power in the long run. Inflation-linked bonds most often come along with lower real yields in comparison to fixed-rate bonds. To put it simply, investors are willing to give up money today in exchange for insurance against inflation tomorrow. Holding inflation-linked bonds is popular amongst institutional investors like pension funds or insurance companies.

2.3.4 Other forms of risk

Another type of risk associated with holding bonds is the liquidity risk. The liquidity risk of a bond refers to the risk that there is no market for the bond, i.e. there is no buyer for a bond an investor wants to sell and/or no seller of a bond an investor wants to buy. The general trading activity represents a good sign of market liquidity. Bonds are generally more liquid during the first weeks and months after issuance.

That is when the largest volume of trading typically occurs. Liquidity risk is greater for thinly traded bonds, such as low-rated or recently downgraded bonds, bonds that were part of a small issue or securities that are sold by an infrequent or small issuer. Demand and supply for a specific bond may also abruptly change due to the risk of unfavorable events. Finally, bonds may have exchange-rate risks.

2.4 The structure of European primary markets

The primary market is the place where sovereign bonds are first issued and sold. Governments use this market to meet their funding requirements by issuing new securities or selling additional amounts of previously issued bonds. Transactions take place between public sector issuers, which is in most cases the country's treasury for the account of the central government, and (mandated institutional) investors.[2] Responsibility for establishing a liquid primary market rests with the national government. Dependent on economic conditions and reputation, the government has to decide on issuance strategies and methods, debt management, risk control as well as investor base and relationships.

2.4.1 Issuance frequency

A first aspect to consider is the regularity of issuance. As Table 2.4 shows, the majority of eurozone countries publish a calender on all planned issues for the year in advance. These issuers try to stick to what they announced, even if changes are possible. Typical announcement details at this time are the type of security, the day of issuance and the day of maturity. In the weeks before the issuance date, most of these issuers refine this information by specifying the targeted nominal amount and further information on the issuance procedure. However, a lot of differences remain across countries. There is a second group of governments, that indicate the next issue only some weeks or days in advance. They do so in a defined timing procedure, e.g. Belgium announces issues on the Monday preceding the issue after

[2] During the last two decades, most member states of the eurozone have established national agencies who carry out these operational activities.

5:00 pm and specifies the information on the Friday morning before the issue. A third group of countries neither publishes a calendar nor indicates the next issue in a consistent manner. This last group consists of Estonia, which does not borrow at the moment, Finland, which publishes an announcement only some days before the issue and Luxembourg, which issues debt securities by bank syndicate on an irregular basis. Table 2.4 summarizes the current state of publishing subdivided by the used announcement procedures of short-term debt obligations and medium to long term bonds.

Table 2.4: Announcement procedures (EA-19)

	Bills	Notes/Bonds
Austria	none	issuance calendar
Belgium	indicative	indicative
Cyprus	indicative	none
Estonia	none	none
Finland	none	none
France	issuance calendar	issuance calendar
Germany	issuance calendar	issuance calendar
Greece	issuance calendar	issuance calendar
Ireland	issuance calendar	issuance calendar
Italy	issuance calendar	issuance calendar
Latvia	indicative	indicative
Lithuania	indicative	indicative
Luxembourg	none	none
Malta	issuance calendar	indicative
Netherlands	issuance calendar	issuance calendar
Portugal	issuance calendar	indicative
Slovakia	indicative	issuance calendar
Slovenia	indicative	none
Spain	issuance calendar	issuance calendar

Notes: The reported announcement procedures are for euro-denominated securities only.
Sources: EU Economic and Financial Committee (2017)

2.4.2 Auction procedure

As of 2017, almost all member states of the eurozone use auctions, also known as tenders, to sell their debt securities. As Table 2.5 shows, exceptions are Estonia and Luxembourg. The latter prefers to use syndicates while the Estonian government follows a conservative fiscal policy regarding borrowing, which has resulted in modest issuance of sovereign bonds during the past. Large continental European countries, like France, Germany or Italy, almost exclusively resort to auctions. Even if some level of co-ordination of national procedures is observable over the last decade, differences remain in frequency, forms of bids, bidding procedures, restrictions of bids, pricing

Table 2.5: Issuance methods used by the EA-19 countries

	Auctions	Syndication	Retail schemes	Others
Austria	yes	yes	yes	yes
Belgium	yes	yes	yes	yes
Cyprus	yes	yes	yes	yes
Estonia	no	no	no	no
Finland	yes	yes	yes	yes
France	yes	rarely	no	no
Germany	yes	no	no	no
Greece	yes	yes	yes	yes
Ireland	yes	yes	yes	rarely
Italy	yes	rarely	yes	rarely
Latvia	yes	yes	yes	yes
Lithuania	yes	yes	yes	rarely
Luxembourg	no	yes	yes	yes
Malta	yes	no	yes	yes
Netherlands	yes	no	no	yes
Portugal	yes	yes	yes	rarely
Slovakia	yes	yes	no	yes
Slovenia	yes	yes	no	yes
Spain	yes	yes	no	rarely

Notes: The reported announcement procedures are for euro-denominated securities.
Sources: EU Economic and Financial Committee (2017)

and settlement.

In general, there are two bidding options within an auction process, which most eurozone member states make use of. Auctions usually start with a competitive bidding phase in which bidders specify the quantity and the bid price, yield or discount margin acceptable to them. The bids must be submitted within a certain time window on auction day and in denominations of EUR 1 million or a multiple thereof. In a subsequent or simultaneous non-competitive bidding phase investors do not specify a bid price but only the quantity they desire to buy. The price is derived from the competitive part of the auction. Most eurozone countries, like France, Italy, Germany and Spain, offer in non-competitive auctions the weighted average price of the competitive bids accepted. Others, like Portugal, guarantee the highest yield accepted in the competitive phase. Both competitive and non-competitive bids are in most cases restricted to mandated financial intermediaries, referred to as primary dealers (see 2.4.3). Bids are submitted either as yields or in the form of prices. Some countries allow both types of bids in their issues, e.g. France or Austria. Others only accept bids in the form of prices (e.g. Germany, Finland, Cyprus). A third group of countries relies on yield bids for a certain type of debt security, e.g. Italian short-term papers (BOTs).

Most eurozone countries require a minimum bid at the auction. It ranges from EUR

1 million in Germany and France to EUR 1.5 million in Italy and EUR 10 million in Belgium. In other countries, investors are obliged to bid for a certain proportion of the issuance volume, e.g. 1/21 in Austrian auctions.[3] Other countries further impose a maximum amount per bid (e.g. Austria, Belgium, Italy and Portugal). In most cases, the maximum volume amounts to 100 percent of the total issue size. In case of large issue sizes, some issuers restrict the upper limit to a smaller proportion than 100 percent. Some countries also have restrictions on the number of bids per investor. For instance, in Italian bonds a bidder can place a maximum of three bids during the auction process. Austria and Germany, among others, leave open the option to cancel an issue whenever the bids are not appealing.

Today's bond auctions usually take place via electronic systems. Belgium, the Netherlands, Finland, Portugal and Ireland use the Bloomberg Auction System. Other countries have their own platforms, like Telsat for French auctions, the Bund Bidding System for German bonds, the National Interbanking Network for Italian debt securities or the Austrian Direct Auction System. Besides electronic bidding platforms, some countries allow other channels to lodge bids, e.g. the Money Market Telephone Service for Spanish auctions.

After the bidding phase, allotment takes place. Two pricing procedures are common. Most eurozone countries rely on the so-called "American procedure", which is a multiple-price procedure. France and Germany, for instance, supply securities at the bid price/yield, i.e. the winning bidders get the price or the rate they actually bid. As a result, investors may pay different prices for the same bond. Who the winning bidders are is determined by a ranking. If bids were in terms of yields, bids are ranked by increasing order of the yields. The bids are alloted in full up to the point where the offering amount is completely allocated. The highest yield accepted is known as the cut-off rate, cut-off yield, or stop-out rate. If bids were in terms of prices, they are ranked by decreasing order of the prices. The lowest price accepted is analogously referred to as cut-off price or stop-out price. The Netherlands, Finland and Spain, among others, use the so-called "Dutch procedure" or variations thereof. The Dutch procedure is a single-price auction. All winning bidders pay only the

[3] At the moment, 21 banks and investment firms are part of the country's primary dealer system.

stop-out rate or stop-out price, i.e. the lowest price or highest yield accepted by the government at the auction. A third group of countries uses both methods. Italy, for instance, makes use of a competitive yield auction for its treasury bills and marginal (single) price auction for medium and long-term bonds. Some countries have further peculiarities in their allotment procedure. For instance, Germany typically sells only about 80 percent of the issuance volume and sets aside the remaining part for market management operations and interventions in the future.

Immediately after the allotment decision, the auction results are reported. Most eurozone countries report information on the competitive and non-competitive nominal amount offered by the bidders, the nominal amount allocated, the weighted average price/yield of accepted bids, the stop-out price/yield and the amount allotted at the stop-out price/yield. Some countries further report the lowest bid price and the highest accepted price or the highest bid yield and the lowest accepted yield (e.g. Austria, Belgium, Italy, Portugal). Spain further reports the first price not allotted. Belgium publishes information on the number of dealers served at an auction. An important measure that is reported by almost all treasuries is the bid-to-cover ratio. The ratio is the total nominal value of all bids divided by the nominal amount issued. The measure indicates the demand for a bond. A bid-to-cover ratio above 2 is considered as strong demand for the security. For instance, the latest issue (May 2017) of a German long-term bond with a term-to-maturity of 30 years and a coupon rate of 2.5 percent has had a bid-to-cover ratio of 2.35 (ISIN: DE0001102341).

After the auction, the treasury delivers bills and bonds to winning bidders. In exchange, it charges the accounts of those bidders for payment. As is shown in Table 2.6, the usual settlement date is T+2. Ireland, Luxembourg, Portugal and Slovenia have a settlement date of T+5 when the issuance follows a syndication. There are some further exceptions for special subscriptions, e.g. Italy has a settlement date of T+3 for zero-coupon and inflation-linked bonds.

2.4.3 Primary dealer systems

Most of the eurozone governments operate in the market through an appointed group of financial institutions. These so-called primary dealers are granted an exclusive

Table 2.6: Market conventions (EA-19)

	Bills				Bonds				
	DCC	Quotation basis	Settlement (PM)	Settlement (SM)	Day count basis	Quotation basis	Settlement (PM)	Settlement (SM)	Coupon freq.
Austria	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	a
Belgium	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	a
Cyprus	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	s/a
Estonia	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	a
Finland	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	a
France	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	a
Germany	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+1-3	a
Greece	ACT/360	decimals	T+3	T+3	ACT/ACT	decimals	T+3	T+3	a
Ireland	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2/5*	T+2	a
Italy	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	s/a
Latvia	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	a
Lithuania	ACT/360	decimals	T+2	T+1	ACT/ACT	decimals	T+2	T+1	a
Luxemb.	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+5*	T+2	a
Malta	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	s/a
Netherl.	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2	T+2	a
Portugal	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2/5*	T+2	a
Slovakia	ACT/360	decimals	T+2	T+0-2	ACT/ACT	decimals	T+2	T+0/1/2	a
Slovenia	ACT/360	decimals	T+2	T+2	ACT/ACT	decimals	T+2/5*	T+0-3**	a
Spain	ACT/360	decimals	T+3	T+2	ACT/ACT	decimals	T+3	T+2	a

Notes: DCC - day count convention. ACT/360 and ACT/ACT are day count conventions which calculate actual days in a 360-day conventional year and 365/366-day year, respectively. The conventional quotation basis is decimal format rather than fractions. Settlement (PM) and settlement (SM) refers to the settlement period in the primary and secondary market. * T+5 for syndicates, ** T+2 on stock exchange and MTS and T+0 to T+3 over-the-counter. a and s/a refers to annual and semi-annual coupon payments.
Sources: EU Economic and Financial Committee (2017)

right to participate in auctions, to be considered for syndicated issues or to get access to the non-competitive bidding process. In addition, many governments inform primary dealers of financial policy issues with priority. In return, primary dealers are subject to certain obligations. These differ from country to country, but they usually include participating in auctions regularly, placing the debt securities in the secondary market and maintaining market liquidity by offering continuous trading opportunities. This is the reason why primary dealers are also referred to as market makers of government securities. They do so on behalf of their clients or for their own account.

To ensure a competitive and liquid market, governments need to attract a sufficient number of domestic and foreign investors. Table A.2 shows the mandated primary dealers in the European sovereign bond markets as of May 2017. The number of primary dealers ranges from five in Latvia to more than 20 in Austria, Greece, Portugal and Spain. Belgium distinguishes between primary dealers, recognized dealers and dealers, who have slightly different rights and obligations. Germany has no official primary dealership system. However, the Bund Issues Auction Group is comprised of credit institutions that have been approved by the Finance Agency of Germany and that have certain obligations as well. Cyprus, Estonia, Luxembourg and Malta do not have a system of primary dealers yet. As displayed in Table A.2, the large global financial institutions (e.g. Barclays, BNP Paribas, Citigroup, Deutsche Bank, Goldman Sachs, J. P. Morgan, Nomura, Royal Bank of Scotland or Sociéte Générale) act as primary dealers in almost every country of the eurozone. Other investors, among them smaller national banks, only act locally. The composition of primary dealers in each country may change from one year to another. Primary dealers that do not meet their obligations are deleted from the list while new institutions are added. Some countries publish an annual ranking of their primary dealers according to primary and secondary market performance.

2.4.4 Further issuance methods

Since the outbreak of the European sovereign debt crisis, the issuance method of syndications has become popular. A syndicate is a temporary group of banks, most often consisting of institutions that are also mandated to participate in the auction procedure. The treasury places debt securities with this group, which then break them up into smaller slices before selling them to other investors. The participants are sometimes called lead managers and co-lead managers. The composition of the syndicate may change for each issue. The technique is fairly common among smaller countries (e.g. Austria, Belgium, Finland, Luxembourg, Portugal). It is also used sometimes by large countries for launching new debt lines (e.g. France, Italy, Spain).[4] Syndicates are also popular on less deep market segments and on the long end of the yield curve. In specific market situations and in case of specific investor demands, it enables the issuer to react in a faster and more flexible way in comparison to a regular auction. However, syndication is usually more expensive because of the fees charged by the banks for managing the sale.

A common issuance method is tap issues. This is a procedure to sell bonds from

[4]For instance, the French treasury recently used a syndication for issuing a green bond. Its money is used exclusively to fund projects that have a positive environmental impact.

past issues. The debt securities are issued at the same maturity and coupon as the outstanding bonds, but sold at current market prices. Often the treasury arranges the placement with a syndicate. The main advantages are to bypass certain transaction or legal costs surrounding a new bond issue, a fast execution and increased liquidity of the outstanding bonds. Countries resort to tap issues for smaller fund-raising attempts, where the cost of a new issue is too high when compared to the amount borrowed. For instance, Finland conducted tap auctions in March and April 2017.

Less frequently used are retail schemes and private placements. Both methods make debt securities available to small investors. Denominations are smaller and more manageable. As Table 2.5 shows, the procedure is used mainly by small countries. For instance, Cyprus issues monthly retail bond series that even allow investors to request an early repayment without penalty. Italy has a large retail bond market as well. However, the largest part of sovereign bond issues takes place in the wholesale market via auctions and syndicates. This market segment is not accessible to private investors.

2.5 Secondary bond market trading

Secondary markets, sometimes referred to as aftermarkets, are financial markets in which securities are bought and sold after they have been issued. Sovereign bonds are traded among investors without any involvement of the issuing government. However, governments play an important role in the organization of secondary market structures by specifying the legal framework, regulations and supervisory mechanisms. This determines the types of negotiations, trading mechanisms, roles for dealers and intermediaries, competition among investors and the level of market transparency. Well-functioning secondary markets are important for the orderly funding of governmental financing needs. It is therefore important for any government to establish structures that ensure an efficient price discovery process and therewith improve liquidity conditions in the market.

2.5.1 Organization of the market

Even if some sovereign bonds are tradable on the central limit order book of exchanges, the largest part of trading occurs over-the-counter (OTC). In other words, bonds are traded directly between two parties without any intermediary.[5] The reasons for this are manifold. First, the asset class of sovereign bonds is heterogeneous. As discussed in Chapter 2.2, sovereign bonds can be classified by a variety of characteristics. This makes it sometimes difficult to find a counterparty for buying or selling a particular asset. Second, bonds are contracts with a fixed maturity, allowing investors to follow a buy-and-hold strategy rather than actively trading in secondary markets. For most bonds, this results in an unstable supply of buyers and sellers in the market. While some sovereign bonds are traded 10,000 times a year, other bonds are traded no more than 10 times a year. This buy-and-hold effect becomes greater towards the bond's date of maturity. Finally, the bond market is dominated by institutional investors, who are interested in large-volume transactions. Regular trade sizes of bonds are between EUR 1 million and EUR 2 million while trades in excess of these amounts are common as well. In the past, trading volumes of more than EUR 100 million were also observable. Trading large quantities, however, could have a strong price impact when they are carried out on a fully disclosed central limit order book.

Sovereign bond trading occurs in so-called quote-driven markets or dealer markets. In the absence of continuous two-way markets, specialized market participants play a crucial role in facilitating transactions. By taking the opposite side of every transaction, dealers act as intermediaries and resolve temporal imbalances in the arrival of buy and sell orders. Grossman and Miller (1988) interpret this intermediary function as "filling the gap". Dealers do so by posting price quotations at which they stand ready to buy and sell the asset. Public investors do not trade directly with each other, but are provided with continuous trading opportunities on both sides of the market. Since dealers are the first who move, dealer markets are referred to as quote-driven markets. They drive price formation and provide liquidity to

[5] The largest part of secondary bond market trading occurs on electronic platforms. It is common to classify these trades as OTC even if the platforms, strictly speaking, work as an intermediary. The electronic trading platforms somewhat blur the traditional distinction between exchanges and the OTC market. For more details see Chapters 2.5.3 and 2.5.4.

the market. The binding price quotations are a commitment to provide the market with an instant opportunity to trade. In sovereign bond trading, primary dealers, who participated in the issuance procedure at the primary market, are most often obligated to provide continuous price quotations in the secondary market.

Sovereign bond markets are physically dispersed. While in a centralized market all price quotations are available in a consolidated and transparent way, a decentralized market is characterized by some degree of fragmentation. Not all price quotations are observable, i.e. simultaneous transactions can take place at different prices. However, this holds true especially for bilateral voice trading, which is used mainly for large trade sizes and less liquid “off-the-run” bonds.[6] A large share of today’s trading is conducted by electronic trading platforms, which goes along with a more centralized organization of bond trading. Due to strict trading rules and higher transparency, these recent electronic facilities somewhat blur the traditional distinction between exchanges and the OTC market.

The main advantages of dealer-organized markets are the continuous availability of tradable prices, enhanced market liquidity and price stability. The provision of market liquidity facilitates efficiency and functioning of the market. The core drawbacks are that dealer markets are less transparent than regular order-driven auction markets, market making has a cost, needs expertise and capital. Furthermore, the European sovereign debt crisis has shown that in times of market uncertainty the posted bids and offers widen and markets become more volatile because liquidity hinges on only a small number of dealers.

2.5.2 Role of dealers

The dealers’ main task is to fill orders either by matching buy and sell orders that already exist in the market, which represents a brokerage service and is also known as agency trading, or by acquiring the position themselves, which is better known as principal trading.

Both the brokerage service and the immediacy service come along with costs.

[6] Off-the-run bonds are securities that have been replaced by the most recently issued benchmark bond within the same maturity bucket.

These can be fixed costs, such as office rent, telecommunication costs, fees and taxes. Additionally, there are variable costs which depend on the underlying asset, its price and quantity traded. In the case of principal trading, dealers stake their own capital and have to build inventory positions, which come along with the risk of unfavorable price developments. In addition, standing ready to buy and sell immediately forces dealers to operate against the market. In a rising market, dealers act as sellers, while they have to make purchases in a falling market. If dealers have the same market expectations as the majority of market participants, they have to hold an unfavorable portfolio structure. These are the reasons why dealers expect to earn an appropriate compensation. The size of compensation depends on dealer's assessment of risk on return. The riskier a position is, the greater the return dealers will demand.

The price at which a dealer signals his interest in buying is called bid price while his selling price is referred to as offer price or ask price. Both prices provide information on dealers' assessment of the fundamental value of an asset. The difference between these two prices determines the bid-ask spread, which represents the dealer's compensation for his service of making the market. A dealer makes profits by selling an asset at a price higher than the price at which he bought the asset net of transaction costs, clearing costs as well as funding, hedging and capital costs. The size of the bid-ask spread is a useful indicator for the liquidity conditions in the market. Besides the bid-ask spread, a dealer further generates income from the earning revenue on his inventory of assets.

2.5.3 Market segments

Figure 2.4 shows two segments of sovereign bond trading, namely business-to-business trading and business-to-customer trading. In the customer market, bilateral trading occurs between dealers and their clients, such as individuals, pension funds, insurance companies, asset managers or corporations. The customer market can be single-dealer oriented or multiple-dealer oriented. In a single-dealer market, the customer receives tradable price quotations during one-to-one contacts with the dealer. This can happen via mail, phone or an internal electronic trading system. Multiple-dealer markets are centered on a trading platform where the customer is able to choose between

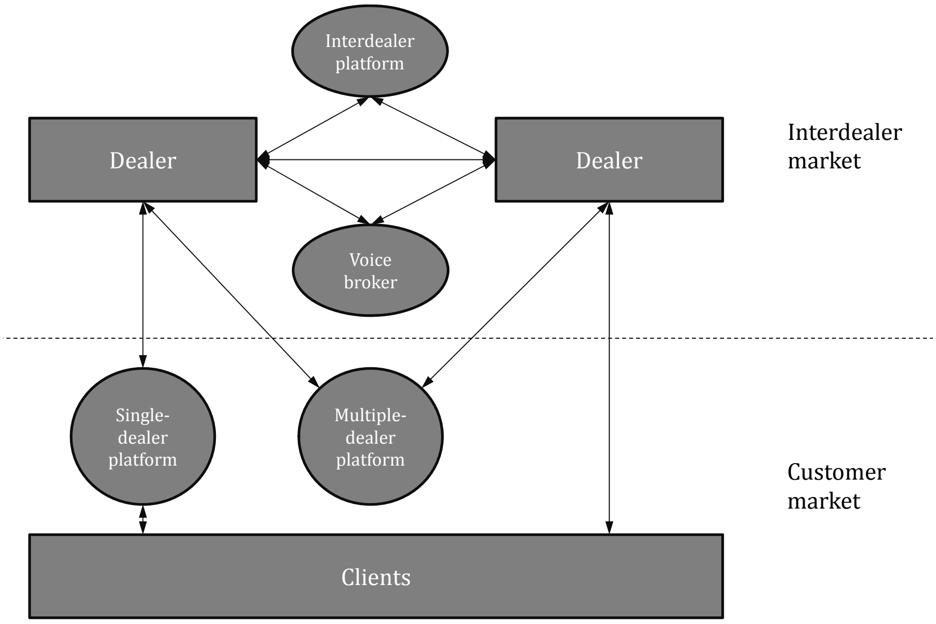


Figure 2.4: Interaction between interdealer and customer markets

price quotations of several dealers. Competition among dealers usually leads to more favorable prices for the clients. Both single-dealer oriented and multiple-dealer oriented electronic platforms emerged in the late 1990s and nowadays more than half of dealer-client trading happens electronically (Committee on the Global Financial System, 2016a).

Next to the customer market there is the interdealer market, which is by far larger concerning overall trading volume. In this market, dealers quote prices to each other. Primary dealers use the interdealer market to fulfill their quoting obligations. Most European governments impose obligations of double-sided price quotations within a maximum spread size, a minimum quantity and for a certain period during the trading day. In addition, business-to-business markets give dealers the opportunity to quickly lay off to other dealers some of the risk from customer trading, such as the acquisition of inventory in excess of requirements. Trading is organized either via electronic trading platforms or voice brokerage. With the aim of liquid and transparent markets, most governments oblige their primary dealers to use electronic trading platforms for the fulfillment of the quotation obligation. Table 2.7 presents a list of mandated platforms by country. The largest providers on the European market are MTS, BrokerTec, BGC and Eurex. Additionally, trading on other electronic platforms and voice trading is possible. Dealers still prefer the telephone line for large transactions and for trading less liquid off-the-run bonds to prevent the market from moving against them. The Committee on the Global Financial System (2016a) estimates the share of electronic trading of US treasuries to amount to about 90 percent, which should be nearly the same for the large eurozone member states. Prices of the interdealer market serve as an important benchmark and feed back price implications for new bond issues on the primary market.

Table 2.7: Mandated platforms for trading European sovereign bonds

	BGC Partners	BrokerTec Europe Ltd	MTS	Eurex Bonds	Other
Austria	x	x	x	x	
Belgium		x	x	x	
Finland	x	x	x	x	
France	x	x	x		
Germany		x	x	x	
Greece			x		HDAT
Ireland	x	x	x		
Italy			x		
Portugal	x	x	x		
Slovenia			x		
Spain			x		SENAF
Netherlands	x	x	x	x	

Notes: Primary dealers can choose one or more trading platforms to fulfill their market-making obligation. Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta and Slovakia do not have mandated trading platforms.
Sources: EU Economic and Financial Committee (2017)

2.5.4 Trading process

The organization of the secondary market affects the way in which prices are formed and trades are determined. It further influences the scope for asymmetric information or strategic behavior, and thus the frictions and transactions costs arising in the trading process. The company managing the trading venue designs the trading rules and mechanisms. This happens most often in collaboration with national treasury agencies.

Even if there are differences among interdealer platforms, registered market makers are generally obliged to quote double-sided prices subject to a maximum spread size and minimum trade quantity. They have to fulfill their obligations during a given minimum of trading hours per trading day. Dealers do so for all benchmark securities and for a number of off-the-run bonds in their portfolios. Dealers submit anonymous price quotations to the (electronic) trading venue. When another dealer's quotations are at the same price, the trading venue works as a broker and automatically cross-matches and executes the orders. Furthermore, all market participants have the opportunity to accept the standing quotes. They can "hit" the bid or "lift" the offer. The regular settlement period is two days. Electronic trading has largely increased price transparency. Since price quotations of many dealers are visible on the screen, other market members are well-informed of changes in prices and the bid-ask spread. These interdealer screens are normally not available to end-customers. However, there exists a large industry of financial services providers, such as Bloomberg, who collect and publish high-frequency price information from different interdealer sources.

In the dealer-to-customer market two types of systems are commonly used. 95 percent of the multiple-dealer customer platforms operate through a request-for-quote protocol (Committee on the Global Financial System, 2016a). On the basis of indicative quotes, an investor has to send a request for a specific trade to the venue. Bids of dealers choosing to respond are fixed for a short period of time. These bids are typically one-sided to either buy or sell the asset. The bids are only visible to the requesting investor. The investor can then choose one of the responding dealers to execute the trade. However, many of today's dealer-to-customer platforms use executable price quotations of a significant number of price contributors that are visible to all investors on the platform. This is the reason why, in this market segment, liquidity and transparency are also relatively high. Leading electronic trading platforms are Bloomberg Electronic Trading, BondVision, Tradeweb and MarketAxess. Bond coverage varies among platforms.

The rise of electronic platforms has opened the doors to automated fixed-income trading. Automated trading means that order and trade decisions are made electronically and without human intervention (BIS, 2011). The operating algorithms are able to submit orders and execute trades within milliseconds. Automated trading is used mainly for three purposes. First, to execute trades with minimized price impact. Therefore, the algorithm splits a large trade into smaller ones, which then are executed over time and across venues. Second, algorithms are used to automatically quote assets and thus make the market without human intervention. The algorithm generates quotes or is used to reply to requests for quotes. Within milliseconds the algorithm tries to profit from the bid-ask spread, while ensuring a low price risk over inventory positions and minimizing the risk of trading with a better informed counterparty. Third, automated trading is used to exploit systematic short-term patterns in prices or to make arbitrage profits from trading in fragmented markets.

The presence of new trading technologies affects the nature of liquidity provision and intermediation in sovereign bond markets. Automated trading is on the rise especially in highly liquid markets with central limit order books, as for futures or benchmark bonds. According to the Committee on the Global Financial System (2016a), over 50 percent of trading volumes in benchmark US sovereign bonds can be accounted for by market participants applying automated trading strategies. In contrast, intermediation in the off-the-run bond market sector is still almost exclusively provided by traditional dealers. In the dealer-to-customer market for US treasury securities, large parts of the trade process are automated. Things look slightly different on the trading platforms for European sovereign bonds. Since interdealer platforms and national treasuries often work together and allow access exclusively to primary dealers, algorithmic trading is less relevant. According to the Committee on the Global Financial System (2016a), most primary dealers still employ human market makers to manually quote assets. Even in the European dealer-to-customer market, dealers most often manually quote on trading requests.

2.6 MTS Cash - interdealer market for trading sovereign bonds

Of particular importance in Europe's secondary bond markets are the trading venues of MTS. Besides an interdealer marketplace (MTS Cash), there is a multi-dealer-to-client trading platform (MTS BondVision), an order-driven market for the transaction of repo agreements (MTS Repo) and a platform for trading multi-currency non-government bonds (MTS Credit). MTS Cash is today's largest interdealer platform for trading European fixed income securities. In view of the fact that the data used in Chapters 4 and 5 stem from MTS Cash, this section focuses in more detail on the platform's institutional background, trading process, market participants and liquidity conditions.

2.6.1 Institutional background

With the aim to improve liquidity and transparency of the Italian sovereign bond market, MTS (Mercato dei Titoli di Stato) was created by the Bank of Italy and the Italian Treasury in 1988. MTS was later privatized and became part of the London Stock Exchange Group in 2007. Within three decades, MTS has expanded to almost all European countries. To facilitate liquid primary and secondary bond markets, MTS works closely together with debt management offices, primary dealers, regulators and central banks across Europe. MTS provides a wide range of trading environments for interdealer and dealer-to-client trading of sovereign bonds, for trading repo agreements and non-government bonds.

MTS Cash is today's largest interdealer platform for trading European fixed income securities. It consists of several domestic trading platforms, where the whole yield curve of sovereign bonds of a country is tradable. Concerning euro-denominated government debt securities, MTS covers the markets of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Slovenia and Spain. Beyond that, local-currency bonds of the Czech Republic, Denmark, Hungary, Israel, Poland and the United Kingdom are tradable. Along with the local markets, MTS operates a pan-European platform for benchmark bonds, EuroMTS.

Due to market regulation purposes, MTS has different shares of interdealer trading across eurozone countries. The share is largest for Greece, Italy and Portugal, where MTS accounts for nearly 100 percent of trading. Due to higher platform competition, the share is lowest for Austrian and German bonds, where MTS accounts for about one third of all business-to-business trades (Dunne et al., 2010). Concerning the overall market share within the eurozone, MTS accounts for more than half of all sovereign bond transactions and represents today's most important interdealer platform for trading euro-denominated fixed income securities. Almost all primary dealers (see Table A.2) trade on the MTS platforms resulting in an average daily turnover of more than EUR 100 billion.

2.6.2 Trading process

Trading on MTS Cash platforms is dedicated to interdealer trading. The electronic system builds on a number of domestic markets and the centralized marketplace EuroMTS. The local platforms are organized as quote-driven markets with a central limit order book. They share the same trading technology, even if each platform has its own set of rules and market participants. All marketable benchmark and non-benchmark bonds of a country are listed and tradable. The trading system is fully automated. Once a dealer has submitted his price quotations anonymously, MTS sorts buy and sell proposals by price and time priority. The best five quotes on either side of the market are published on the limit order book. Every change in the five best bid and ask quotes is immediately visible on the screen to all market participants. Trades are executed when standing quotes are either hit by incoming orders or automatically matched with opposite-side proposals of another dealer in the market. Executed trades are immediately and automatically reported.

On the centralized EuroMTS platform only benchmark bonds are tradable. To reward benchmark status, sovereign bonds must have been issued within the previous two years with total par value of at least EUR 5 billion. Due to high market liquidity, EuroMTS is nowadays organized as an order-driven market allowing all market participants full functionality and no quoting requirements in accessing the order book. The fact that benchmark bonds can be traded on EuroMTS and a local platform makes parallel price discovery processes possible. However, the domestic market and the European reference market essentially constitute one single venue. Cheung et al. (2005) show that trading costs and liquidity are closely linked on these platforms. Pelizzon et al. (2013) report further that market participants are provided with price updates from both venues on a consolidated screen. In addition, the number of participating market makers is in many cases the same in both marketplaces. Since most dealers participate on both platforms, price consistency is likely.

The clearing and settlement process is initiated immediately after trades are executed. Once a trade has been executed, MTS reveals the counterparty for clearing and settlement purposes. All market participants must be members of a clearing institution. Settlements can be conducted in either form of net delivery against payments or gross delivery versus payment basis depending on the type of debt instruments and markets. The regular settlement period is three days for bonds and two days for short-term securities.

The market opens at 8:15am and closes at 5:30pm CET/CEST. Before, there is a pre-market phase (7:30-8:00am) during which market members can insert, change and view their own price quotations. During the following 15 minutes, market participants can post price quotations and submit orders, but no automatic matching occurs. This becomes possible from 8:15am onwards. Regular trading days are from Monday to Friday. No trading is possible on weekends and after 5:30pm.

2.6.3 Market participants

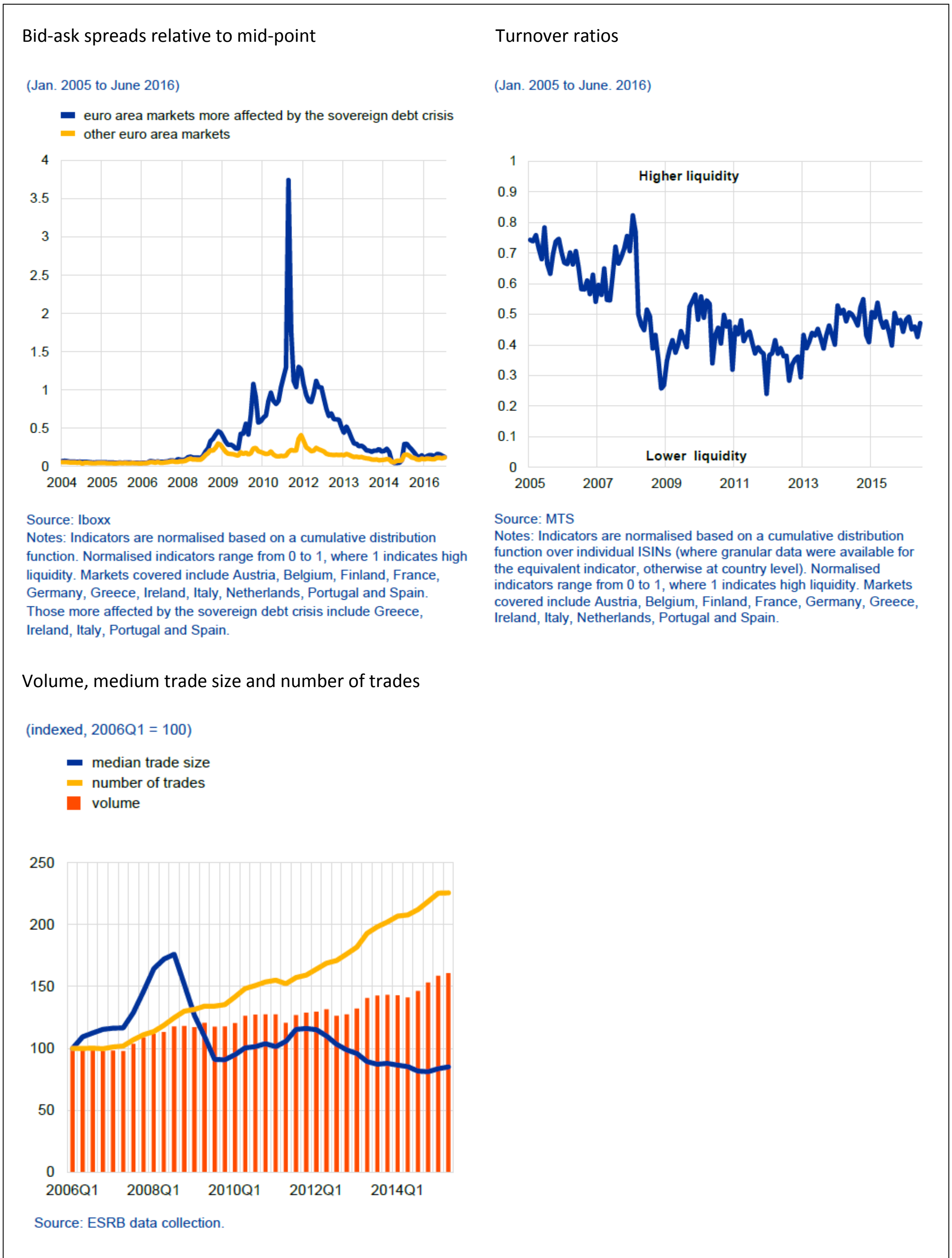
In the quote-driven local markets two types of market participants interact, primary dealers and other secondary market participants. To be eligible as primary dealer, institutions must satisfy stringent requirements both in terms of net asset values and trading volumes on MTS during the previous year. These authorized dealers must fulfill market-making obligations for specific securities. They must therefore commit to provide two-sided price quotations for a minimum of five hours during a trading day, below a maximum spread, and for minimum quantities ranging from EUR 2.5 to EUR 10 million. Quoting obligations for primary dealers have been relaxed since the onset of the global financial crisis. MTS monitors average quoting times and spreads of a dealer, which must be in line with averages across all dealers (Baker and Kiymaz, 2013). In addition to prices, a dealer indicates the overall size he is willing to trade, the so-called block quantity, and the fraction of that quantity he is willing to show, better known as drip quantity. However, MTS reports that the ratio of hidden to displayed orders is less than two percent.

Primary dealers can voluntarily provide quotes for any other security for which they have no market-making obligations. For benchmark bonds trading in parallel on a local platform and the EuroMTS platform, dealers are able to post quotes simultaneously on both markets. Primary dealers are also active on the buy-side of the market, i.e. they submit market orders to trade against the best available quotes of other dealers. In this role, they have no obligation to buy or sell at the standing quotes. According to MTS, 96 percent of all market orders are submitted by primary dealers.

2.6.4 Liquidity conditions

MTS Cash is not only Europe's largest platform for fixed income trading, but also the most liquid trading venue. Market liquidity is the ease with which large-volume transactions can be executed rapidly at low cost and with limited price impact (Committee on the Global Financial System, 1999). The literature has recognized three dimensions of liquidity: tightness, depth and resiliency (Garbade, 1982, Kyle, 1985, Harris, 1990). The tightness of a market indicates how far bid and ask prices diverge from the mid-market price. It represents the general costs of trading. The tightness of a market is often measured by the quote-based bid-ask spread or the trade-based effective spread. Depth refers to the volume that is possible to trade without affecting prevailing market prices. A proxy often used is the quoted depth, which is the amount of orders in the order book. Another measure is the size of trades market makers are willing to accept. The third dimension of liquidity is resiliency, which refers either to the duration of price fluctuations after trades or the speed with which imbalances in order flows are neutralized. An approach to measure resiliency is to examine the development of the bid-ask spread or order volume and how long it will take until normal market conditions are restored. Other proxies of market liquidity are the traded volume and the number of trades, trade frequency, turnover ratio, price volatility as well as the number of market participants and market makers in the market (Committee on the Global Financial System, 1999, 2014).

The European Systemic Risk Board (2016) has analyzed liquidity conditions in the euro area sovereign bond markets and on MTS platforms over the last 10 years. They show that many measures indicate a decline in market liquidity compared with the pre-crisis era before 2007. Compared with liquidity conditions during the peak of the



Source: European Systemic Risk Board (2016)

Figure 2.5: Liquidity measures

banking and sovereign debt crisis, markets show higher liquidity recently. However, proxies differ in terms of the extent of the decline over recent years. As Figure 2.5 shows, the bid-ask spreads relative to their midpoint price have fallen considerably compared with the peaks during the crisis, but remain well above pre-crisis levels. Turnover ratios are below pre-crisis levels on average which confirms the decline in market liquidity. However, MTS reports an average round trip time of transactions of less than 0.323 milliseconds at the moment, with 99.9 percent of transactions below 6ms. The European Systemic Risk Board (2016) shows that the average deal size traded on MTS is slightly below pre-crisis levels.

Figure 2.5 shows three further indicators of market liquidity, namely trading volume, median trade size and number of trades. Since the outbreak of the crisis, trading volumes have increased at an annual rate of 4 percent (European Systemic Risk Board, 2016). The measure, however, should be considered with caution because trading volume largely correlates with the level of bond issuance in the primary market. The development comes along with a decreasing median trade size (from EUR 18 million in Q3/2008 to EUR 9 million in Q2/2015) and an increasing number of trades. Both developments speak in favor of less liquid markets because large trades need to be split in order to execute a trade for a reasonable price and within an acceptable time frame.

Pelizzon et al. (2013) study liquidity on the MTS Cash platforms for trading Italian sovereign bonds for the period between June 2011 and November 2012. They are able to show that bid-ask spreads for 15- and 30-year bonds are widest during the crisis, while 10-year bonds exhibited relatively tight spreads. Primary dealers seem to differentiate between bonds of different maturities under stressed conditions. They further show that illiquid bonds have a contagion effect and cause worsening of illiquidity in the whole market. Another important observation is that during the crisis, a considerable fraction of market makers left the market. This increased the imbalance between quote revisions and resulting trades. Finally, the authors are able to show that liquidity of Italian bonds improved after the intervention by the European Central Bank through its Long-Term Refinancing Operations (LTRO) and Outright Monetary Transactions (OMT) programs.

2.7 Conclusions

Bonds are an important asset class for governments to finance general and specific budget expenditure or to refinance existing debts. They are further used by central banks to conduct open market operations for the management of liquidity and interest rates in the financial system. Besides its role as a policy tool, sovereign bonds serve as benchmarks in pricing corporate debt. From a portfolio management perspective, they represent an important asset class that allows money managers to balance portfolios and hedge risks.

Even if European national treasuries have made an effort to harmonize their debt obligations over the course of last decades, the asset class remains highly heterogeneous. The chapter gave an introduction to the differences in terms, structures, requirements and other details. Besides explanatory notes on the terminology of bonds and associated investment risks in general, we made reference to the specific conditions within the member states of the European Union, which together represent the world's largest and most diversified market for debt securities.

In the further course of the chapter, we introduced the peculiarities of European primary markets. Governments use these markets to meet their funding requirements by issuing new securities or selling additional amounts of previously issued bonds. Dependent on economic conditions and reputation, they have to decide on issuance strategies and methods, debt management, risk control as well as investor base and relationships. Afterwards, we concentrated on secondary markets and showed that well-functioning aftermarkets are important for the orderly funding of governmental financing needs. Even if sovereign bonds are traded among investors without any involvement of the issuing government, the latter plays an important role in the organization of secondary market structures by specifying the legal framework, regulations and supervisory mechanisms. This determines the types of negotiations, trading mechanisms, roles for dealers and intermediaries, competition among investors and the level of market transparency. In view of the fact that the data used in Chapters 4 and 5 stem from MTS Cash, we concentrated finally on the institutional background, trading process, market participants and liquidity conditions of this trading venue, which represents the most important business-to-business trading platform for European fixed income securities.

A Appendix

Table A.1: Rating scales of three major rating agencies

S&P	Moody's	Fitch	Description
AAA	Aaa	AAA	Prime / highest quality / highest ability to repay debt
AA+ AA AA-	Aa1 Aa2 Aa3	AA+ AA AA-	High grade / very strong ability to repay debt
A+ A A-	A1 A2 A3	A+ A A-	Upper medium grade / strong ability to repay debt
BBB+ BBB BBB-	Baa1 Baa2 Baa3	BBB+ BBB BBB-	Lower medium grade
BB+ BB BB-	Ba1 Ba2 Ba3	BB+ BB BB-	Non investmentgrade / speculative
B+ B B-	B1 B2 B3	B+ B B-	Highly speculative
CCC+ CCC	Caa1 Caa2	CCC CC	Substantial risks / extremely speculative
CCC- CC C	Caa3 Ca	(CC) C	In default with little prospect for recovery
SD D	C	RD D	In default

Sources: Standard & Poor's (2017b), Moody's (2017a), Fitch Ratings (2017a)

Table A.2: List of authorized primary dealers in the European sovereign bond markets (May 2017)

	AT	BE	FI	FR	DE	GR	IE	IT	LT	LV	NL	PT	SK	SI	ES	Total
ABANKA VIPA														x		1
ABLV BANK										x						1
ABN AMRO					x						x					2
ALPHA BANK						x										1
BANCA IMI					x	x		x								3
BANCO BPI												x				1
BANCO SANTANDER					x						x	x			x	4
BANKHAUS LAMPE					x											1
BANKIA															x	1
BANKINTER															x	1
BARCLAYS BANK	x	x	x	x	x	x	x	x			x	x	x	x	x	13
BAWAG P.S.K.	x															1
BAYERISCHE LANDESBANK					x											1
BBVA					x							x			x	3
BHF-BANK					x											1
BNP PARIBAS	x	x	x	x	x	x	x	x				x		x	x	11
CAIXA GERAL DE DEPOSITOS												x				1
CAIXABANK															x	1
CANTOR FITZGERALD IRELAND							x									1
CECABANK															x	1
CITADELE BANKA									x	x						2
CITIGROUP GLOBAL MARKETS	x	x	x	x	x	x	x	x			x	x	x	x	x	13
COMMERZBANK	x			x	x	x					x			x	x	7
CRÉDIT AGRICOLE		x	x	x	x			x				x			x	7
CREDIT SUISSE						x										1
DANSKE BANK			x		x		x		x			x			x	6
DAVY							x									1
DEKABANK					x											1
DEUTSCHE BANK	x		x	x	x	x	x	x			x	x	x	x	x	12
DNB BANK									x	x						2
DZ BANK					x											1
ERSTE GROUP BANK	x												x			2
EUROBANK ERGASIAS						x										1
GOLDMAN SACHS INTERNATIONAL BANK	x		x	x	x	x	x	x			x	x		x	x	11
HELABA					x											1
HSBC FRANCE	x	x	x	x	x	x	x	x			x	x	x	x	x	13
ING BANK		x			x	x		x			x					5
J.P. MORGAN SECURITIES	x	x	x	x	x	x	x	x				x		x	x	11

Table A.2: (continued)

	AT	BE	FI	FR	DE	GR	IE	IT	LT	LV	NL	PT	SK	SI	ES	Total
JEFFERIES INTERNATIONAL					x						x	x		x		4
JOH. BERENBERG, GOSSLER									x							1
KBC SECURITIES		x											x			2
LANDESBANK BW	x				x											2
MERILL LYNCH INTERNATIONAL	x		x	x	x	x	x	x								7
MILLENIUMBCP												x				1
MIZUHO					x											1
MONTE PASCHI DI SIENA								x								1
MORGAN STANLEY & CO INTERNATIONAL	x	x		x	x	x	x	x				x			x	9
NATIONAL BANK OF GREECE						x										1
NATIXIS	x	x		x	x						x		x		x	7
NOMURA INTERNATIONAL	x	x	x	x	x	x	x	x			x	x			x	11
NORDDEUTSCHE LANDESBANK					x											1
NORDEA			x		x						x					3
NOVA LJUBLJANSKA BANKA														x		1
NOVO BANCO												x				1
OBERBANK	x															1
OESTERREICHISCHE VOKSBANKEN	x															1
PIRAEUS BANK						x										1
RABOBANK					x						x					2
RAIFFEISEN BANK INTERNATIONAL	x															1
R. BANK OF SCOTLAND/NATWEST MARKETS	x	x	x	x	x	x	x	x			x	x			x	11
SCOTIABANK					x											1
SEB									x	x						2
SIAULIU BANKAS									x							1
SOCIÉTÉ GÉNÉRALE	x	x	x	x	x	x	x	x			x	x	x	x	x	13
SWEDBANK									x	x						2
TATRA BANKA													x			1
UBS				x	x	x	x	x								5
UNICREDIT BANK AG	x				x	x		x					x	x		6
VSEOBECNA UVEROVA BANKA													x			1
Total	21	13	14	16	36	22	16	18	7	5	16	20	11	13	21	

Notes: Cyprus, Estonia, Luxembourg and Malta do not have a system of primary dealers. Officially, Germany has no primary dealership system. However, the Bund Issues Auction Group comprises credit institutions that have been approved by the Finance Agency of Germany.

Sources: Austrian Treasury (2017), Belgian Debt Agency (2017), Republic of Finland - Central Government Debt Management (2017), République Francaise - Agence France Tresor (2017), Bundesrepublik Deutschland - Finanzagentur GmbH (2017), Republic of Greece - Public Debt Management Agency (2017), Republic of Ireland - National Treasury Management Agency (2017), Italian Ministry of Economy and Finance - Treasury Department (2017), Ministry of Finance of the Republic of Lithuania (2017), Republic of Latvia - Treasury (2017), Dutch State Treasury Agency (2017), Agencia de Gestao da Tesouraria e da Divida Publica (2017), Slovak Republic - Debt and Liquidity Management Agency (2017), Republic of Slovenia - Ministry of Finance (2017), Ministerio de economia, industria y competititvidad (2017)

3 Insights from market microstructure theory on dealer markets

Abstract

The focus of this chapter is on the theoretical analysis of market-making activities of liquidity suppliers and its implications for the price formation process in dealer markets. We follow the evolution of the theoretical literature on market microstructure and discuss different sources of trading costs a monopolistic dealer is confronted with, namely order processing costs, inventory holding costs, and adverse selection costs. Since most of today's trading in European sovereign bonds is characterized by a multiple dealer structure, we turn our attention later to a competitive market-making framework and study the role of interdealer trading on the price formation process. The chapter closes with a summary of empirically testable price implications.

3.1 Introduction

Market microstructure is a research area of economics and finance concerned with the simplest form of financial intermediation: the trading of a financial asset (Stoll, 2003). As O'Hara (1995) states, it is "the study of the process and outcomes of exchanging assets under a specific set of rules". What distinguishes market microstructure theory from standard microeconomic market models is the importance of this "specific set of rules". The field of theoretical, empirical, and experimental research investigates how the organizational form of trading, trading rules and processes, as well as associated trading costs and market frictions affect the price formation process (Madhavan, 2000).

The research field is closely linked to the investment literature, which studies the equilibrium values of financial assets. It is also related to the field of corporate finance because differences between the price and value of assets clearly affect financing and capital structure decisions (Madhavan, 2000). The aim of the present chapter is to shed light on the decision and action processes of market participants in sovereign bond markets based on the insights of the market microstructure theory.

In the previous chapter we described in detail the design of sovereign bond markets as well as the characteristics of market participants. The latter can be defined by investors' status of information, their preferences and endowments. We came to realize that sovereign bonds are a relatively heterogeneous asset class and trading is characterized by temporary imbalances in the inflow of buy and sell orders. To ensure continuous trading, fixed income markets are therefore often structured as dealer markets in which at least one market participant offers immediacy service by posting executable bid and offer prices. A central question in the field of market microstructure on dealer markets is that of the determinants of the spread between these two prices.[7]

The academic literature on market microstructure focuses on the supply side of the market and decomposes the bid-ask spread into three types of accruing costs a dealer wants to be compensated for: order processing costs, inventory holding costs, and adverse selection costs. The order-processing component reflects the dealer's compensation with respect to his expenditures for service provision like salaries, the exchange seat, floor space rent, costs of technical equipment or informational service costs. This component is assumed to be largely fixed, i.e. the costs are independent of the transaction size. The inventory component concerns the role of the dealer's asset endowment. Holding a specific position induces costs such as opportunity costs or the costs of carrying the price risk. Inventory costs were first discussed by Garman (1976), Stoll (1978), Amihud and Mendelson (1980), Ho and Stoll (1981), Mildenstein and Schleef (1983), O'Hara and Oldfield (1986) and Madhavan and Smidt (1993), among others. The adverse selection component of the bid-ask spread

[7]The market microstructure theory in its entirety is extensively discussed in O'Hara (1995), Madhavan (2000), Hasbrouck (2007), and De Jong and Rindi (2009), among others.

deals with the risk arising when a dealer is confronted with better informed investors in the market. If some market participants have superior information on the true value of an asset they are able to make arbitrage profits by buying securities that they believe are underpriced and selling assets that are overpriced. The role of information distribution is the focus of analytical work by Copeland and Galai (1983), Glosten and Milgrom (1985), Kyle (1985), Easley and O'Hara (1987) and Admati and Pfleiderer (1988), among others.

Since modern electronic markets of sovereign bond trading do not have a monopolistic structure but feature many market participants with market-making obligations, we further analyze the implications of a multiple dealer structure. Under competition some important differences in pricing should be expected. On the one hand, competition puts in place the probability of not having the most attractive prices, which results in another market maker winning the bid from an outside client. On the other hand, interdealer trading becomes possible, and with it strategic behavior among dealers themselves. Valuable contributions stem from Ho and Stoll (1983), Biais (1993), Lyons (1997), Evans and Lyons (2002) and Dunne et al. (2015), among others.

The organization of this chapter corresponds to these strands of research. After a short introduction on the rationale behind bid-ask spreads (3.2), Sections 3.3 and 3.4 concentrate on inventory- and information-based models. Later on, Section 3.5 focuses on a competitive market structure including interdealer trading. In Chapter 3.6, we discuss important implications for the short-term price behavior in sovereign bond markets, which lay the foundation for the following chapters.

3.2 Rationale behind bid-ask spreads

Demsetz (1968) came up with the first formal model in which the existence of a bid-ask spread is analyzed explicitly against the backdrop of liquidity costs. He works out the role of a monopolistic market maker using the example of the so-called specialist on the New York Stock Exchange (NYSE). The specialist's ordinary service is to manage orders, i.e. to match an incoming buy order with an incoming sell order.

For his service of information repository he asks for a brokerage commission. In addition to that, the specialist overcomes the problem of asynchronous order flows by posting instantaneously tradable buy and sell prices. If he does so, he acts for his own account and does not earn any share of commissions. The specialist offers his immediacy service whenever he expects to resell the asset at a higher price than he paid initially.

The core idea of the market maker's immediacy service is illustrated in the static supply and demand framework of Figure 3.1. The monotonically increasing supply curve S represents the aggregated interest of all market participants who desire that their sell orders of asset i be serviced immediately. The monotonically decreasing demand curve D represents the aggregated interest of all market participants to immediately buy asset i. The Walrasian equilibrium then emerges in the intersection of both curves. Suppliers and consumers would immediately trade the equilibrium quantity q^* at the market clearing price of p^*. This equilibrium price is often referred to as "true" price of the asset which would exist in a perfect world without any market frictions.

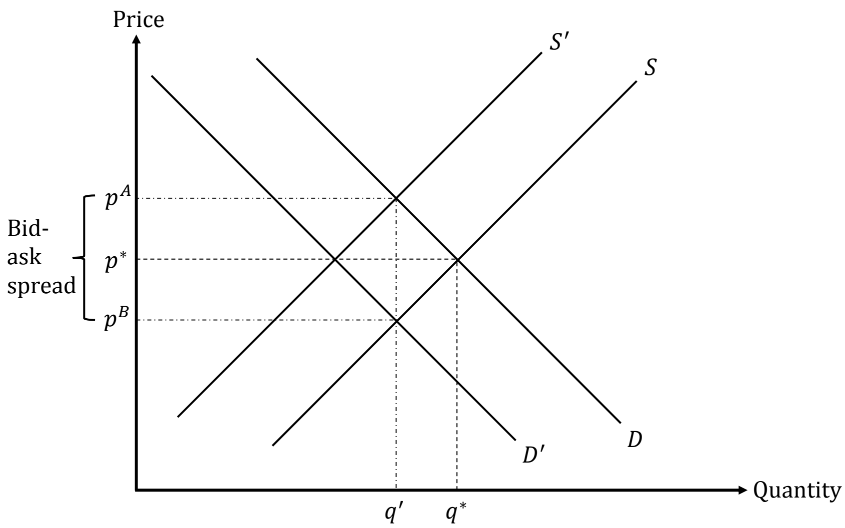


Figure 3.1: Demand and supply with and without immediacy service (Demsetz, 1968)

However, in many financial markets we observe asynchronous buy and sell order flows. A market participant wishing to sell shares of asset i at price p^* cannot automatically count on the immediate presence of a buyer. The same holds true for the demand side of the market. To solve the problem of unbalanced order flows a dealer is installed. The dealer is the one who always stands ready to buy and sell at stated prices immediately upon receipt of a matching order.

Of course, to offer his service of immediacy the dealer requests for a compensation. He is willing to buy asset i at a price that is below p^* and to sell at a price that is above p^*. The difference between these two prices—the bid-ask spread—represents the market maker's turnover. As Figure 3.1 depicts, this is illustrated by two supply and demand functions in the market: the supply and demand curves of the regular market participants (S, D) who want an immediate execution of their orders, and the supply and demand functions of the market-making dealer (S', D') who is willing to wait and serve all incoming orders. S' is located slightly above S and D' is located slightly below D to cover the dealer's cost of waiting. These four functions deliver two equilibrium prices in the market. From the intersection of the supply curve of the market maker, S', and the demand curve of the other market participants, D, the dealer's selling price, p^A, arises. The intersection of his demand curve, D', with the market supply function, S, generates the purchase price of the dealer, p^B. The spread between p^A and p^B measures the price of immediacy. Demsetz (1968) defines these liquidity costs of trading as "the markup that is paid for predictable immediacy of exchange in organized markets".

Demsetz (1968) further analyzes the extent to which transaction costs are affected by the scale of trading. The lower the ask and the higher the bid price offered by a dealer, the shorter the waiting period should be for incoming market orders. Thus, the fundamental force working to reduce the bid-ask spread is the time rate of transactions. Another force is the number of dealers in the market. When we have more than one market maker, it is expected that they try to submit competitive quotes to be at the head of the trading queue and thereby reduce the waiting time. The market spread will be smaller. Bollen et al. (2004) even argue that in highly competitive markets, the bid-ask spread should equal the expected marginal cost of supplying liquidity.

By his approach to argue the existence of the bid-ask spread by the market maker's service of immediacy, Demsetz (1968) laid the foundation for the market microstructure theory. The aim of the following sections is to determine the specific value of immediacy service, to specify the associated costs for the market maker and to derive his optimum quotation strategy.

3.3 Inventory models

This section examines the optimal price-setting behavior of market makers in managing inventory and shows how the size of the bid-ask spread can compensate for the inventory risk. Section 3.3.1 starts with the seminal work of Garman (1976) arguing that a dealer has limited cash and asset resources. Therefore, he faces the risk of running out of cash (bankruptcy) or out of inventory (failure). Section 3.3.2 introduces the model of Amihud and Mendelson (1980), which is an extension of the Garman model but concentrates on the dealer's market power as source of the bid-ask spread. Section 3.3.3 introduces explicitly the assumption of a risk-averse market maker within the model framework of Stoll (1978). Against the background of the global financial crisis, Section 3.3.4 focuses on the article of Brunnermeier and Pedersen (2009) who examine how market liquidity is affected by dealers who face capital constraints.

3.3.1 Risk of bankruptcy

The market model of Garman (1976) builds on the assumption of a monopolistic market maker who commits himself to ensure immediate trading opportunities for an asset. This forces him to hold both cash and asset inventory. The basic idea of the model is that the market maker's quotation strategy depends on his capital and asset endowment. His objective is to make a living by trading on the temporary fluctuations' of supply and demand subject to avoiding bankruptcy and failure.

The underlying model assumptions are:

1. All transactions are executed via a single monopolistic market maker. No direct trading between buyers and sellers is permitted.

2. The market maker sets his bid price, p^B, and ask price, p^A. Based on these quotations other market participants can carry out their orders.

3. Buy and sell orders arrive randomly in continuous time. The Poisson-distributed arrival rates $\lambda^{buy}(p^A)$ and $\lambda^{sell}(p^B)$ are price-dependent. The order size, q, is assumed equal to 1.

4. At t_0, the market maker has cash and security inventories of I_0^c and I_0^s, respectively.

5. The market maker's objective is to maximize his expected profit per unit of time subject to avoiding $I_t^c \leq 0$ and $I_t^s \leq 0$.

6. There are no other causes of costs for the market maker.

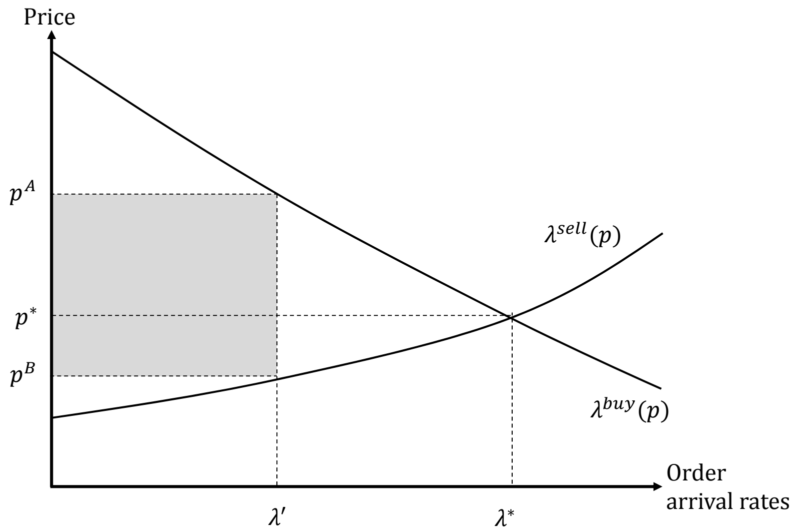


Figure 3.2: Bid-ask prices subject to the market maker's risk of bankruptcy and failure (Garman, 1976)

The arrival intensity functions of buy and sell orders are depicted in Figure 3.2. Garman (1976) refines the classic Walrasian equilibrium with a stochastic analogue of a monotonically decreasing demand function and a monotonically increasing supply function. Here, market clearing means that buy and sell orders arrive at the same average intensity rate. The modeling of the order arrival rates as Poisson-distributed processes leads to the stochastic equilibrium (p^*, λ^*) in Figure 3.2.

To overcome market imbalances, a market maker stands ready to buy and sell the asset. He has to offset a wide spread accompanied by a high profit on each trade on the one hand and a small spread associated with a high rate of arrivals on the other hand (shaded area in Figure 3.2). His optimization strategy lies in the maximization of this area. To accommodate for the asynchronous stochastic order arrival, the market maker needs to maintain inventory in both assets and cash. Meanwhile, he has no ability to borrow either cash or securities. Thus, his quoting strategy depends on his initial portfolio position. The essential mechanism in the model is that the market maker sets his quotes to elicit an expected imbalance of orders.

Dealer's inventories at time t can be represented by

$$I_t^c = I_0^c + p^A N_t^{buy} - p^B N_t^{sell}, \tag{3.1}$$

and

$$I_t^s = I_0^s + N_t^{sell} - N_t^{buy}, \tag{3.2}$$

where I_0^c and I_0^s are the dealer's opening positions in cash and assets, and N_t^{buy} and N_t^{sell} are the total numbers of executed buy and sell orders since the beginning of trading. The dealer's objective is to maximize his expected profit subject to avoiding bankruptcy and failure. This formulation gives rise to a classic gambler's ruin problem. On the basis of equations 3.1 and 3.2 Garman approximates the ultimate bankruptcy and failure probabilities as a function of the market maker's price strategy.

Let $\pi_t^c(k)$ be the probability that his cash equals k at time t and $\pi_t^s(k)$ be the probability that his asset inventory equals k at time t. Since the order size equals one, there may be three events that yield a cash position of k units: in $t = 0$, the dealer had $k - 1$ units of cash and sold one asset; the dealer had $k + 1$ units of cash and bought one asset; or the dealer did not trade. Then the dynamics of the dealer's cash inventory can be approximately described by

$$\begin{aligned} \mathrm{d}\pi_t^c(k)/\mathrm{d}t =& p^A\lambda^{buy}(p^A)\pi_t^c(k-1) \\ &+ p^B\lambda^{sell}(p^B)\pi_t^c(k+1) \\ &- \left\{p^A\lambda^{buy}(p^A) + p^B\lambda^{sell}(p^B)\right\}\pi_t^c(k). \end{aligned} \tag{3.3}$$

A similar equation can be derived for the dynamics of the dealer's asset inventory. Analyzing the embedded Markov chain in this stochastic process yields the approximate ultimate probability of running out of cash

$$\begin{aligned} \lim_{t\to\infty}\pi_t^c(0) &\approx \left(\frac{p^B\lambda^{sell}(p^B)}{p^A\lambda^{buy}(p^A)}\right)^{I_0^c/\overline{p}}, \quad \text{if } p^A\lambda^{buy}(p^A) > p^B\lambda^{sell}(p^B), \\ &= 1 \qquad \text{otherwise}, \end{aligned} \tag{3.4}$$

where $\overline{p}$ is chosen such that $p^A > \overline{p} > p^B$. By similar means the ultimate probability of running out of assets yields

$$\begin{aligned} \lim_{t\to\infty}\pi_t^s(0) &\approx \left(\frac{\lambda^{buy}(p^A)}{\lambda^{sell}(p^B)}\right)^{I_0^s}, \quad \text{if } \lambda^{buy}(p^A) < \lambda^{sell}(p^B), \\ &= 1 \qquad \text{otherwise}. \end{aligned} \tag{3.5}$$

To avoid certain failure the dealer must set p^A and p^B so as to satisfy

$$p^A\lambda^{buy}(p^A) > p^B\lambda^{sell}(p^B), \tag{3.6}$$

and

$$\lambda^{sell}(p^B) > \lambda^{buy}(p^A). \tag{3.7}$$

Satisfying both equations simultaneously requires that $p^A > p^B$. By setting p^A above p^B, the dealer protects himself from certain failure or bankruptcy, although he still faces positive probabilities for both. Under the less restrictive assumption that inventories are infinite, the market maker will set prices which will equate the arrival rates of buy and sell orders at some value $\lambda' = \lambda^{buy} = \lambda^{sell}$, as is depicted in Figure 3.2. The shaded area represents the market maker's expected profit per unit time. Since transactions occur for both buy and sell orders, the transaction volume equals $2\lambda'$, which is, of course, below the market volume under perfect competition, $2\lambda^*$.

Garman's key contribution to the literature is the theoretical implementation that a dealer's inventory may affect his viability. Further, the model has some important price implications. For example, dealers who already hold a long position may be reluctant to take on additional inventory without significant price reductions. This may lead to alternate price changes and increasing price volatility.

3.3.2 Abuse of market power

In the Garman model, the market maker sets his quotes only once before trading starts. If the following transactions result in an unwanted portfolio structure, adjustments are not provided. This is quite unrealistic as in reality prices continually evolve. Amihud and Mendelson (1980) address this issue by modeling the market maker's quote strategy as a function of his intended portfolio structure. In this way, it is one of the first models, in which inventory control is modeled explicitly.

The properties of the market considered in the paper of Amihud and Mendelson (1980) are quite similar to the dealership market introduced by Garman (1976). The underlying model assumptions are:

1. All transactions are executed via a single monopolistic market maker. No direct trading between buyers and sellers is permitted.
2. The market maker sets his bid price, p^B, and ask price, p^A. Based on these quotations other market participants can carry out their orders.
3. The arrival of buy and sell orders in the market is modeled by two independent Poisson processes. The next incoming order will be a buy order with probability $D(p^A)/(D(p^A)+S(p^B))$, or a sell order with probability $S(p^B)/(D(p^A)+S(p^B))$. The time until the next incoming order has an exponential distribution with mean $1/(D(p^A)+S(p^B))$.
4. The market maker's inventory of the asset is constrained to lie between exogenously given upper and lower bounds.
5. The market maker's objective is to maximize his expected profit which is defined as net cash flow per unit time.

6. There are no other causes of costs for the market maker.

Due to the discrepancy between supply and demand, the process of inventory development is a birth-death process. Thus, the model incorporates a semi-Markov decision process in which inventory is the state variable. The dealer's bid and ask prices are the decision variables which depend on the level of the state variable. In other words, the bid and ask prices may change over time as the level of inventory changes. The arrival processes of buy and sell orders are identical to those assumed in Garman's model. The demand and supply rates are dependent on the dealer's ask and bid prices. Further, Amihud and Mendelson assume that inventory is bounded above and below by exogenous parameters. These limitations may result from capital requirements or administrative rules. A potential insolvency is therefore eliminated from the model. This allows a tighter focus on the market maker's optimization problem.

From the market demand and market supply functions Amihud and Mendelson conduct the market maker's revenue R and cost functions C. $R(\lambda^{buy})$ is the expected sales revenue for each period in dependence of the market demand rate λ^{buy} (which is, in turn, a function of the pre-determined ask price):

$$R(\lambda^{buy}) = \lambda^{buy} * p^A(\lambda^{buy}) = \lambda^{buy} * D^{-1}(\lambda^{buy}). \tag{3.8}$$

Accordingly, $C(\lambda^{sell})$ represents the expected cash outflow for each period in dependence of the market supply rate λ^{sell}. It represents replacement purchases of the market maker for the recovery of his securities portfolio due to previous sales:

$$C(\lambda^{sell}) = \lambda^{sell} * p^B(\lambda^{sell}) = \lambda^{sell} * S^{-1}(\lambda^{sell}). \tag{3.9}$$

The corresponding bid-ask spread is

$$\Delta(\lambda^{sell}, \lambda^{buy}) = p^A(\lambda^{buy}) - p^B(\lambda^{sell}). \tag{3.10}$$

By means of a differential analysis, Amihud and Mendelson are able to show that bid and ask prices are monotone decreasing functions of a dealer's inventory position. The model also predicts that the optimal ask is always above the optimal bid price, which reflects dealer monopoly. The authors further figure out that the quoting strategy of the market maker comprises a preferred risk structure of the portfolio (see Figure 3.3). Temporary deviations from the preferred inventory position lead the market maker to increase or decrease his quotes so that the probability of order executions on the desired market side increases. By a sustainable shift in the quotations it is even possible to reduce the order arrival rate to zero. The authors show that the bid-ask spread is smaller in close vicinity to the target structure of the market maker's portfolio. Accordingly, large deviations result in a larger bid-ask spread. Finally, the profit-maximizing market maker has a permanent interest in trading because rising revenues lead, ceteris paribus, to an increase of his profits.

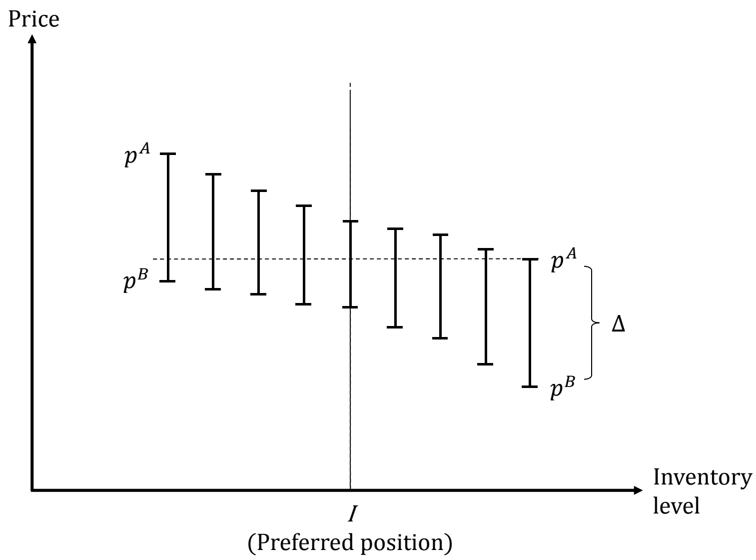


Figure 3.3: Bid-ask prices as a function of the market maker's inventory position (Amihud and Mendelson, 1980)

3.3.3 Risk-return tradeoff

The Amihud and Mendelson model only implicitly implies risk aversion in that the market maker wants to reduce deviations from his desired inventory position. In contrast, Stoll (1978) explicitly models a market maker who is interested in a portfolio structure that is in line with his risk-taking behavior. Since the dealer has to accommodate the trading desires of other market participants, his actual and desired inventory positions diverge, resulting in an inferior utility level. The dealer uses the bid-ask spread to encourage transactions that rebalance his inventory back to target structure. In other words, the bid-ask spread arises as compensation for the price risk and opportunity cost of holding inventory and reflects the dealer's aversion of risk.

The underlying model assumptions are:

1. All transactions are executed via a single monopolistic market maker. No direct trading between buyers and sellers is permitted.

2. The market maker sets his bid price, p^B, and ask price, p^A. Based on these quotations other market participants can carry out their orders.

3. Asset purchases by the market maker are financed by borrowing at the risk-free interest rate, R_f, and the proceeds of short sales are invested solely in a risk-free asset.

4. The risk-averse market maker is assumed to have a utility function over terminal wealth.

5. On the basis of fundamental characteristics of the traded asset the market maker estimates the "true" equilibrium price and knows its performance. This estimate need not be the same as the estimates of other market participants. Transaction costs are not included.

6. The dealer makes one transaction per trading interval. Prices can only change between two trading periods. At the end of the second trading interval the market maker's inventory is liquidated at the equilibrium price.

On the basis of the portfolio theory, Figure 3.4 depicts the considerations of a utility-maximizing market maker in the Stoll model. His favored securities portfolio lies on the capital market line, which starts in R_f and represents all linear combinations of the risk-free interest rate and the market portfolio M. The latter includes all risky investment alternatives in the market. The market maker's investor-optimal portfolio

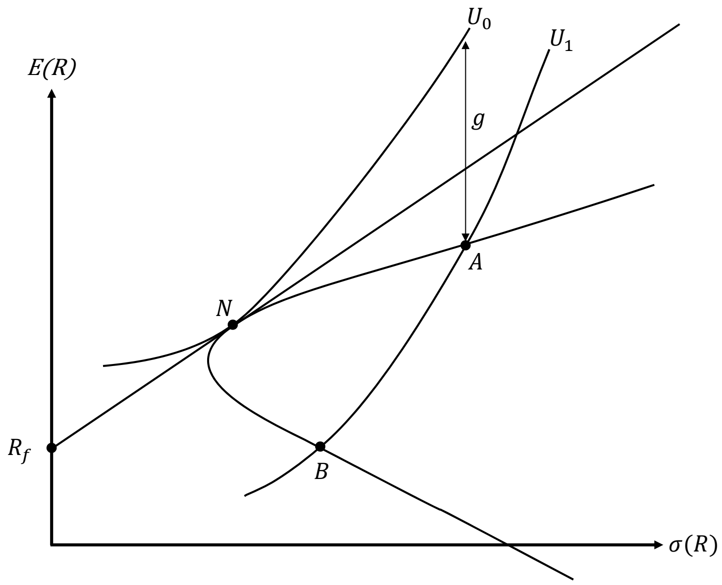


Figure 3.4: Risk aversion in the model of Stoll (1978)

N lies on the capital market line tangent to his indifference curve U_0. The provision of immediacy causes the market maker to make transactions that alter his portfolio away from N. Asset purchases, for instance, may result in the suboptimal portfolio A, sales could result in portfolio B. Both deliver him a lower utility level U_1. The difference g between U_0 and U_1 reflects the inventory holding costs of portfolio A. To get compensated for this costs, the market maker will quote the asset accordingly. He sets his bid price below and his ask price above the "true" price of the asset. The question is how large this discount has to be?

Under the assumption the market maker is risk-averse and structures his portfolio accordingly, he stands ready to make the market for asset i only if expected utility of terminal wealth of the new portfolio after the transaction, $\tilde{W}$, is equal to expected utility of terminal wealth of his initial investor-optimal portfolio, $\tilde{W}^*$:

$$E[U(\tilde{W}^*)] = E[U(\tilde{W})]$$

or

$$E[U(W_0(1+\tilde{R}^*))] = E[U(W_0(1+\tilde{R}^*) + (1+\tilde{R}_i)Q_i - (1+R_f)(Q_i - C_i))], \quad (3.11)$$

where W_0 represents the initial wealth of the market maker's investor-optimal portfolio and $\tilde{R}^*$ is the associated insecure rate of return. Q_i is the "true" market value of the transaction in asset i, $\tilde{R}_i$ is the associated insecure rate of return and C_i represents the costs/proceeds to the dealer of trading Q_i. Thus, the terminal wealth under the new portfolio is given by the compounded initial portfolio, the compounded value of the transaction in asset i minus the compounded difference between the market value and the costs/proceeds of the transaction.

Stoll derives the inventory holding cost function by assuming R_f is small enough to be ignored and by applying a Taylor series expansion around the mean wealth $\overline{W}$ and dropping the terms of order higher than two:

$$\frac{C_i}{Q_i} = c_i(Q_i) = \frac{z}{W_0}\sigma_{ip}Q_p + \frac{1}{2}\frac{z}{W_0}\sigma_i^2 Q_i. \tag{3.12}$$

The percentage holding costs, c_i, are then a function of the market maker's relative risk aversion z, his initial wealth W_0, the size of the initial position in the trading account Q_p, the size of the transaction in asset i, Q_i, and some characteristics of asset i, namely the covariance σ_{ip} between the return on asset i and the return on the initial inventory and the variance of return on asset i, σ_i^2.

For market depth of Q_i^B the market maker sets his bid price, P_i^B, below the "true" price by the proportion c_i:

$$\frac{P_i^* - P_i^B}{P_i^*} = c_i(Q_i^B). \tag{3.13}$$

Accordingly, for market depth of Q_i^A he sets his ask price, P_i^A, above the "true" price:

$$\frac{P_i^A - P_i^*}{P_i^*} = c_i(Q_i^A). \tag{3.14}$$

The discount is greater the greater the market maker's relative risk aversion, the smaller his initial wealth, the greater the asset's return variance, and the larger the quoted depth.

Under the assumption that inventory costs are the only source of the spread and that $Q_i^B = Q_i^A = |Q_i|$, the proportional bid-ask spread is given by:

$$s_i = \frac{P_i^A - P_i^B}{P_i^*} = c_i(Q_i^B) - c_i(Q_i^A) = \frac{z}{W_0}\sigma_i^2|Q_i|. \quad (3.15)$$

Thus, the spread is determined by the dealer's general risk averseness, his initial wealth, the variance of return and the size of the transaction. Initial inventory will affect only the placement of the bid and ask prices, but not necessarily the size of the spread. After a sale at the bid, for instance, both bid and ask price are lowered. At this moment the number of shares of asset i exceeds the dealer's investor-optimal number of shares. Thus, he lowers his bid to discourage additional sales to him, and lowers his ask to encourage purchases from him. Correspondingly, after a market purchase at the ask, both prices are raised. Due to his risk-averseness, the dealer is always interested in pushing back his portfolio to the target level. Since the model is based on the individual preferences of the dealer concerning the risk-return-profile of his portfolio, the model provides an explanation of why bid-ask spreads vary when they are quoted by different dealers. The model can be extended to account for multiple periods, assets, and dealers, without altering the essential features (see e.g. Ho and Stoll (1981) and Ho and Stoll (1983)).

3.3.4 Funding constraints

Many inventory models assume (at least implicitly) that dealers have access to unlimited additional capital. In contrast, Brunnermeier and Pedersen (2009) examine how market liquidity is affected by the inventory of a market maker who faces capital constraints. Their model is a natural extension of the model of Grossman and Miller (1988) with the added feature that dealers face "real-world" funding constraints. In the model the market maker is assumed to be risk-neutral and his objective is to maximize terminal wealth subject to the constraint that the amount of capital required to finance his inventory positions (total margin) cannot exceed his total capital.

The authors are able to show that when the margin requirements come closer to a dealer's available capital, he provides less liquidity to the market and bid-ask spreads widen. At that point market prices are more driven by funding liquidity considerations rather than by movements in fundamentals. The model further implies that very large inventory positions lead to wider spreads. Furthermore, when large inventory positions push a dealer close to his capital constraints, he provides liquidity mostly in low-risk securities causing a "flight-to-quality". This lowers market liquidity and increases volatility of high-margin assets.

As we have shown so far, inventory models predict that dealers set ask prices above bid prices, that they adjust both bid and ask prices to avoid too large positions on one side of the market and that they may or may not change the magnitude of their bid-ask spreads as their inventory changes, depending on model specifications. A core drawback of inventory models is that the market maker is only able to discriminate between different types of traders on the basis of the trading volume. Another drawback of these models is the assumption that order flows are uncorrelated with future price developments. In reality, however, order flows contain information about the market participants' perception of fundamentals. A class of microstructure models that distinguishes between different types of traders and the role of information in the price discovery process is the class of information models.

3.4 Information models

Information is important in financial markets as it may trigger expectations, price changes, and transactions. Up until now, the dealer has been confronted with only one type of counterparty, namely non-strategic liquidity traders. Now he is assumed to face a further type of market participants, so-called insiders. Insiders have superior non-public information about the future value of an asset, while the market maker and liquidity traders do not. Because insiders have the option of not trading with the dealer, he will never gain but always lose in trading with them. He is only able to gain in his transactions with liquidity traders, which is why he sets a positive bid-ask spread. Section 3.4.1 introduces the rational expectations model of Grossman and Stiglitz (1980), which analyzes explicitly the price-relevance of private information. Section 3.4.2 introduces the model of Copeland and Galai (1983). They change to the perspective of a market maker and show that he sets a bid-ask spread to balance expected losses against informed traders and expected gains from uninformed liquidity traders. The sequential trade model of Glosten and Milgrom (1985) is discussed in Section 3.4.3. They are able to show that a positive bid-ask spread always exists if information is distributed asymmetrically in the market. This is even the case when the market maker is assumed to be risk-neutral and forced to make zero-profit under competition.[8]

3.4.1 Price-relevance of information

The following considerations are based on the work of Grossman and Stiglitz (1980). On the basis of a simple rational expectations model the authors are able to show that a heterogeneous distribution of information affects prices. Although the model is highly stylized, it yields some important implications on the role of information and represents a good starting point to information-based microstructure models.

The model assumptions are:

1. All transactions are executed via a single monopolistic market maker. No direct trading between buyers and sellers is permitted.
2. Besides the market maker, there are two other types of market participants, informed traders I and uninformed (liquidity-motivated) traders U.
3. The market consists of two assets, of which one has a (risky) random payoff V. Only I receives a private signal about payoff V.
4. All market participants have the same absolute risk aversion parameter z.
5. Aggregate supply S is exogenous.
6. The model abstracts from any lending and borrowing costs.

I and U receive a signal about the value V of the security. U only receives a public signal $V = \overline{V} + \epsilon_V$, so that $V \sim N(\overline{V}, \sigma_V^2)$. I receives an additional private signal

[8] Even though there is another strand of information models, of which the model of Kyle (1985) represents the most prominent example, we decided to not discuss it in detail. The focus of these strategic trade models is not on the market maker but on the insider who behaves strategically by considering the price impact of his trade size.

$X = V + \epsilon_X$ with $X|V \sim N(V, \sigma_X^2)$. Combining both signals, the public information and private signal, I's conditional distribution of the value is

$$\begin{aligned} E(V|X) &= E(V) + \sum_{VX} \sum_{XX}^{-1} (X - E(X)) \\ &= (1-\beta)\overline{V} + \beta X \end{aligned} \tag{3.16}$$

$$\begin{aligned} Var(V|X) &= \sum_{VV} - \sum_{VX} \sum_{XX}^{-1} \sum_{VX}^{'} \\ &= (1-\beta)\sigma_V^2 \leq \sigma_V^2 \end{aligned} \tag{3.17}$$

where $\beta = \sigma_V^2(\sigma_V^2 + \sigma_X^2)^{-1}$. Equation 3.16 indicates that I expects a value equal to a weighted average of public information and private signal. Equation 3.17 shows that I's information is more accurate. The informed variance is smaller than the uninformed variance, σ_V^2.

Both traders generate wealth by trading the risky asset. They maximize an exponential utility function $E[U(W)] = E[-exp(-zW)] = -exp(-zE[W] + \frac{1}{2}z^2 Var(W))$, in which wealth is $W = d(V - p)$. Wealth is stochastic and normally distributed. The maximization of $E[U(W)]$ with respect to asset demand d gives $d = \frac{E[V]-p}{zVar(V)}$. Hence, the optimal demand schedules d_U and d_I are given by

$$d_U = \frac{E(V) - p}{zVar(V)} = \frac{\overline{V} - p}{z\sigma_V^2} \tag{3.18}$$

and

$$d_I = \frac{E(V|X) - p}{zVar(V|X)} = \frac{\beta X + (1-\beta)\overline{V} - p}{z(1-\beta)\sigma_V^2}. \tag{3.19}$$

The aggregate demand observed by the market maker equals

$$D \equiv d_U + d_I = \frac{1}{z\sigma_V^2}\left(2\overline{V} + \frac{\beta}{1-\beta}X - \frac{1}{1-\beta}p\right). \tag{3.20}$$

Under the market clearing condition $D - S = 0$, solving for equilibrium price yields

$$p = (1-\beta)\overline{V} + \beta X - \frac{1}{2}z(1-\beta)\sigma_V^2 S. \tag{3.21}$$

Equation 3.21 shows that the equilibrium price is a weighted average of public mean $\overline{V}$ and private signal X minus a compensation for risk aversion. More importantly, the equilibrium price p depends on the private signal X. Although U does not observe X, he knows that I's trade affects the market makers' price and thus can extract information about the private signal from equilibrium price. In the special case that aggregate supply S is fixed, the market price reveals the private signal completely, i.e. $d_U = d_I$.

This result is rather striking. If information is costly and the price system is fully revealing, the equilibrium cannot be stable. Superior information can only generate extra profit if X is not revealed immediately. Otherwise, every trader is willing to stay uninformed, which is also known as the Grossman-Stiglitz paradox of the impossibility of informationally efficient markets. However, the model is a good starting point as it shows the impact of private information on prices and how the latter perform an important role in revealing information. Copeland and Galai (1983) build on the basic ideas, but change the focus to the market maker's risk of trading with better informed investors, which forces him to set a bid-ask spread.

3.4.2 Systematic losses

Copeland and Galai (1983) were the first who formally analyzed the market maker's optimization problem if information is asymmetrically distributed among market participants. The market maker does not know about the degree of information his counterparty in trading has. However, he expects to systematically lose to informed traders, who only trade when they expect to gain, and to gain from transactions with liquidity traders, who are willing to pay a markup in order to obtain immediacy. The article of Copeland and Galai (1983) models the market maker's bid-ask spread as a tradeoff between expected losses and expected gains both in a monopolistic and competitive setting.

The underlying model assumptions are:

1. All transactions are executed via one (or more) market maker(s). No direct trading between buyers and sellers is permitted.

2. Besides the market maker, there are two other types of market participants, informed traders I and uninformed (liquidity-motivated) traders U.

3. The market maker sets his bid price, p^B, and ask price, p^A. Based on these quotations other market participants can carry out their orders.

4. The "true" price of the asset, P, follows a stochastic process, $f(P)$, which is known (ex ante) to all market participants.

5. Price-changing information is generated by exogenous events and conveyed to the market by insiders. Market makers and liquidity traders are uninformed as to the realizations of $f(P)$ until after an informed trade takes place.

6. The market maker is not able to distinguish insiders from liquidity traders, but he knows the probabilities that the next order comes from an informed market participant, π^I, or a liquidity trader, $\pi^U = 1 - \pi^I$.

7. The risk-neutral market maker is assumed to have a utility function over terminal wealth.

8. The demand functions of both insiders and liquidity traders are price elastic.

9. The model abstracts from any lending and borrowing costs.

The objective of the market maker is to set his prices in such a way that his expected profit is maximized. A wide bid-ask spread comes along with a high compensation for his service of immediacy per trade but leads to low trade interest in the market. With a wide spread the market maker reduces potential losses to informed traders, but waives revenues from liquidity traders. In contrast, a narrow spread guarantees a high trading volume but increases the likelihood that insiders arrive in the market. Therefore, the aim of the market maker should be to choose a spread that balances the gains from trading with non-informed market participants and losses on transactions with informed traders.

The information arrival process can be characterized as follows. Private information on the asset under consideration is revealed first to an informed trader. The

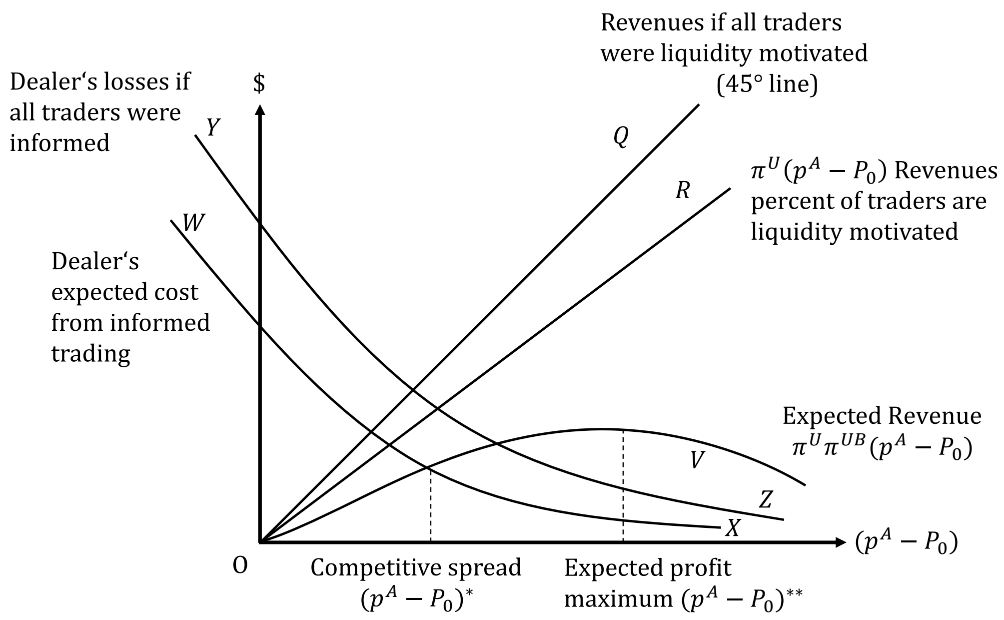


Figure 3.5: The market maker's optimization problem in the model of Copeland and Galai (1983)

information arrival is modeled as a continuous or discontinuous stochastic process. The informed market participant will trade whenever he expects to make a good bargain. Before trading, the market maker knows the probability that the next trader is informed, π^I, or not informed, π^U. Copeland and Galai (1983) assume that these probabilities are bounded in the sense that neither all traders have superior information ($\pi^I \neq 1$), nor that all traders are liquidity-motivated ($\pi^I \neq 0$). After the trade, any private information becomes public. The dealer may then revise his estimate of the true price.

The dealer's expected losses stem from informed traders. These losses will depend on the probability that the next trader is informed π^I, the dealer's knowledge of the stochastic price process $f(P)$, on his prices p^A and p^B, and the price elasticity of demand. Under the assumption that the quantity traded is one unit, the expected loss is

$$\pi^I \left\{ \int_{p^A}^{\infty} (P - p^A) f(P)\,\mathrm{d}P + \int_0^{p^B} (p^B - P) f(P)\,\mathrm{d}P \right\}, \tag{3.22}$$

where P designates the post-trade "true" price of the asset. Informed traders that expect the post-trade price will fall between p^A and p^B will not make use of the trading option. Hence, the price elasticity of demand by informed traders is implicit in the limits of integration of Equation 3.22. The dealer's expected losses to informed traders are graphed as line WX in Figure 3.5. Along the horizontal axis only the ask spread (one part of the bid-ask spread) is depicted. As the ask spread increases, expected losses to informed traders will decline.

The dealer's expected revenues stem from liquidity traders who are willing to pay $p^A - P_0$ or $P_0 - p^B$, respectively. In order to express the price elasticity of demand by liquidity traders, Copeland and Galai partition the liquidity traders into those who trade and those who do not trade. The probabilities of arriving at the marketplace are π^{UT} and π^{UN}, respectively. They further decompose π^{UT} into the probability of buying π^{UB} and selling π^{US}. The dealer's expected profit from transactions with liquidity traders is than calculated as

$$(1-\pi^I)\left\{\pi^{UB}(p^A - P_0) + \pi^{US}(P_0 - p^B) + \pi^{UN}\cdot 0\right\}. \tag{3.23}$$

The expected revenue curve is graphed by line OR in Figure 3.5. When we multiply this by π^{UB} (i.e. the probability of a liquidity trader buying at the ask), the resulting expected revenue curve is OV. The function is concave if π^{UB} decreases monotonically as a function of p^A.

The market maker has to choose a bid-ask spread which maximizes his expected profit:

$$\begin{aligned} max_{p^A,p^B}\Big\{&(1-\pi^I)\left[\pi^{UB}(p^A - P_0) + \pi^{US}(P_0 - p^B)\right] \\ &-\pi^I\left[\int_{p^A}^{\infty}(P-p^A)f(P)\,\mathrm{d}P + \int_0^{p^B}(p^B - P)f(P)\,\mathrm{d}P\right]\Big\} \geq 0. \end{aligned} \tag{3.24}$$

If we have a single monopolistic market maker, he maximizes the difference between the expected cost and revenue functions by setting the ask price p^{A**} in Figure 3.5. In contrast, in a competitive setting the ask price p^{A*} establishes since here expected costs and revenues are equal (long-run profit is zero).

The model of Copeland and Galai (1983) delivers important price implications. First, even if the market maker is assumed to be risk-neutral, the bid-ask spread will be positive as long as there are informed traders in the market. Second, the larger the share of informed traders in the market, the larger the bid-ask spread the market maker requests. Third, the spread is larger in the monopoly than in the competitive case. If the percentage share of informed traders increases, however, the difference between these two market scenarios decreases. Copeland and Galai further show that the bid-ask spread is a positive function of the price level and return variance and a negative function of measures of market activity, depth, and continuity.

3.4.3 Sequential trading

The model of Glosten and Milgrom (1985) confirms and generalizes the results presented in Copeland and Galai (1983). While the latter model assumes that non-public information is revealed immediately after each trade, Glosten and Milgrom (1985) allow additional transactions until informational differences between insiders and other market participants are gone. Thus, they have a tighter focus on the dynamic properties of the bid-ask spread and transaction prices after an event that gives an informational advantage to insiders.

The assumptions of the model are:

1. All transactions are executed via a single market maker. No direct trading between buyers and sellers is permitted.

2. Besides the market maker, there are two other types of market participants, informed traders I and uninformed (liquidity-motivated) traders U.

3. The market maker sets his bid price, p^B, and ask price, p^A, so that he achieves an expected zero profit. After a trade, the market maker may revise his prices.

4. The traded asset has a random future liquidation value V, which is executed in T_0. Before T_0 the value is only known to insiders.

5. Trading is anonymous. The market maker only knows the probabilities that the next order comes from an informed market participant, π^I, or a liquidity

trader, $\pi^U = 1 - \pi^I$.

6. All market participants are risk-neutral and maximize their expected utility given their information.

7. There are no transaction costs, inventory holding costs or any other type of costs.

There is a single asset, whose terminal value can either be high $V = V^+$ in the case of good news or low $V = V^-$ in the case of bad news. The probability for good news arriving to the market is π^{V^+} and the probability for bad news is $(\pi^{V^-} = 1 - \pi^{V^+})$. All informed traders initially observe whether the terminal value of the asset is high or low. In contrast, the market maker only knows the ratio of informed and uninformed traders in the market. Insiders trade with probability π^I, while liquidity traders trade with probability $(\pi^U = 1 - \pi^I)$. In the presence of good news insiders always decide to purchase, while in the presence of bad news insiders are always ready to sell. In contrast, liquidity traders act as a buyer with the probability π^{UB} and as a seller with the probability $(\pi^{US} = 1 - \pi^{UB})$. The trading process is shown in Figure 3.6.

The market maker has no information on the true value of the asset V but forms expectations by observing market order flow. For instance, a buy order B signals him that the true price could be higher than his quoted ask price p^A. A sell order S conveys information about the true value that could be below his quoted bid price p^B. Since the market maker does not know whether the order stems from an insider or a liquidity trader, however, the trading signal that he receives is not clear. To exploit best the market-induced information, Glosten and Milgrom form conditional probabilities according to the Bayes' theorem. For instance, the conditional probability of a buy order B in the case of good news V^+ is

$$\pi^{B|V^+} = \frac{\pi^{B,V^+}}{\pi^{V^+}} = \frac{\pi^{V^+}\pi^I + \pi^{V^+}(1-\pi^I)\pi^{UB}}{\pi^{V^+}}. \tag{3.25}$$

Analogously, it is possible to calculate the conditional probabilities for the emergence of a sell order in case of good news V^+ as well as the emergence of a buy or sell orders in case of bad news V^-. Figure 3.6 illustrates the emergence of buy and sell orders depending on the type of news and market participants.

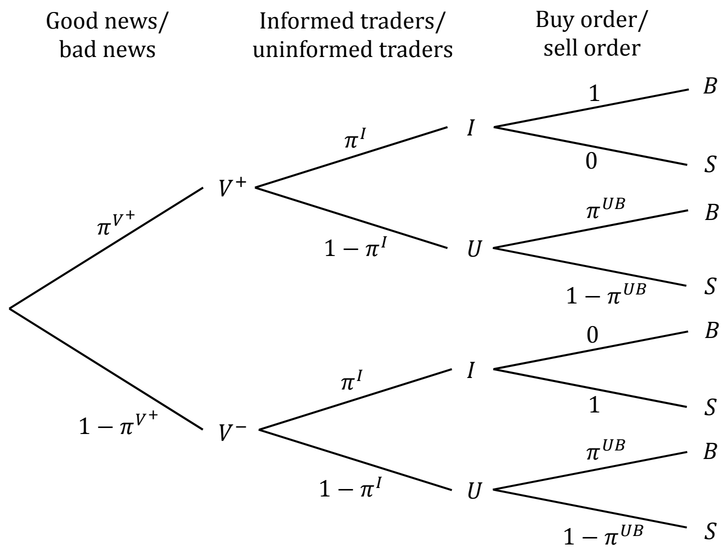


Figure 3.6: Probability distribution of buy and sell orders (Glosten and Milgrom, 1985)

Under the assumption of a competitive market structure, the risk-neutral dealer sets his bid price p^B and his ask price p^A so that it corresponds to the conditional expectation of the true value of the asset.

The bid price can be calculated as

$$p^B = E[V|S] = V^+ * \pi^{V^+|S} + V^- * \pi^{V^-|S}. \tag{3.26}$$

The dealer's ask price can be calculated as

$$p^A = E[V|B] = V^+ * \pi^{V^+|B} + V^- * \pi^{V^-|B}. \tag{3.27}$$

The conditional probabilites in 3.26 and 3.27 can be calculated using the Bayes' theorem:

$$P(A|B) = \frac{P(B|A)P(A)}{Pr(B)}. \tag{3.28}$$

For example, the likelihood of a high value of the asset in the case of a buy order is

$$\pi^{V^+|B} = \frac{\pi^{V^+} * \pi^{B|V^+}}{\pi^{V^+} * \pi^{B|V^+} + \pi^{V^-} * \pi^{B|V^-}}. \tag{3.29}$$

Analogously, the conditional probabilities for good news when there is a sell order and bad news in the cases of a buy order or sell order can be determined. Each order represents an information signal for the market maker, which causes him to reconsider his expectations on the true value of the asset.

The model delivers important implications. First, the bid and ask prices depend on the probability of buy and sell orders in the market. Second, the size of the bid-ask spread depends on the probability of insiders in the market, which illustrates the effect of adverse selection. If $\pi^I = 0$, the risk of market makers to suffer losses from transactions with insiders does not exist. The bid-ask spread would be zero. If $\pi^I = 1$, only insider trading exists. Thus, the first order arriving to the market is a perfect information signal for the market maker on the true value of the asset. In this case, the market maker sets the largest spread possible to protect himself from losses. However, since insiders are indifferent to trading to the prevailing bid-ask spread and trading abstinence, the market would dry up. The model further shows that price dynamics follow a martingale, that is, the expectation of p_{t+1} based on all information available at time t is p_t. In other words, this implies that prices are semi-strongly efficient, depending on the information available to the market maker. Finally, as each transaction reveals information, the expectations of all market participants converge with respect to the true value of the asset. The bid-ask spreads tend to decline over time. Easley and O'Hara (1987) consider an extension to the Glosten and Milgrom (1985) model in which traders may submit orders of different sizes. In general, informed traders prefer to trade larger amounts to benefit from their information advantage as much as possible. They argue that market makers' pricing strategy must take into account the trade size, with large trades being made at less favorable prices. Furthermore, since large orders are an indicator of private information, insider's advantage drops away.

3.5 Multiple dealer models

The theoretical models presented so far concentrate foremost on a single market maker. The secondary market for sovereign bonds is, like the options and foreign exchange market, better characterized by a multiple-dealer setup. Under competition some important differences in pricing should be expected. For one thing, competition puts in place the probability of losing a trade from an outside client against another market maker. For another thing, interdealer trading becomes possible, and with it strategic behavior among dealers themselves. There is a collection of papers studying multiple dealer frameworks and interdealer trading behavior. Ho and Stoll (1983) were the first to discuss the role of competition between market makers. They show that relative inventory positions among dealers give rise to interdealer trading. Another result is that dealers with the most extreme inventory will execute all trades by quoting the most competitive prices. However, the model of Ho and Stoll (1983) has some drawbacks, like the assumptions that dealer inventories are public information and that customer trades and interdealer trades are carried out in the same market. Biais (1993) supports the findings of Ho and Stoll and is further able to show that the number of market makers in the market depends on the volatility of the asset and the general trading activity in the market. Lyons (1997) and Evans and Lyons (2002) explain the so-called "hot potato" trading in foreign exchange markets, i.e. a repeated passing of inventory among dealers, and show that this creates additional noise in the order flow.[9]

The model of Dunne et al. (2015) is one of the first which takes the two-tier structure of bond markets into account. In the model a dealer has access to both the customer market and the interdealer market. Since clients have no access to the interdealer market, they have to trade directly with a dealer. This results in an intermediation function of dealers across market segments of different competitiveness. While the interdealer market is assumed to be highly competitive, the dealer has some level of market power in the customer market.

[9]Further contributions stem from Leach and Madhavan (1993), Dutta and Madhavan (1997), Flood et al. (1999), among others.

The model assumptions are:

1. In the customer market, dealers face stochastic requests for buy and sell quotes with a constant probability. A customer decides to buy when his reservation price exceeds the ask price in the market, $p^{AR} > p^{\hat{A}}$, and sells when his reservation price is below the current bid price in the market, $p^{BR} < p^{\hat{B}}$. Private customer values have a uniform distribution with density d over the interval $[x_{t+1}, x_{t+1} + d^{-1}]$ and $[x_{t+1} - d^{-1}, x_{t+1}$ for the ask and the bid, i.e. more unfavorable quotes reduce the chance of customer acceptance. The midprice x_{t+1} is a stochastic martingale process. Standardized ask quotes are defined as $p^A = p^{\hat{A}} - x_t$ and standardized bid quotes as $p^B = p^{\hat{B}} - x_t$.

2. Dealers have access to an interdealer market to manage their inventory. At this market they can buy inventory at the best competitive ask price $p^{\hat{a}}$ and sell inventory at the best competitive bid price $p^{\hat{b}}$. The bid-ask spread is defined as $S = p^{\hat{a}} - p^{\hat{b}} > 0$. The prices are conintegrated with the price process x_t, so that $p^{\hat{a}} = x_t + 0.5S$ and $p^{\hat{b}} = x_t - 0.5S$. Accordingly, the standardized prices are $p^a = p^{\hat{a}} - x_t = 0.5S$ and $p^b = p^{\hat{b}} - x_t = -0.5S$.

3. The risk-neutral dealer chooses his quotes for the customer market in order to maximize the expected payoff under an inventory constraint. The inventory level can either be 1, 0 or -1. The dealer is required to liquidate any inventory above 1 or below -1 in the interdealer market. Due to the zero-profit condition in the interdealer market, the dealer neither gains, nor loses by trading with other dealers.

The sequence of trading is depicted in Figure 3.7.

A dealer's value function is defined as $V(s, x_t)$. The state variable s represents one of the three possible inventory levels. A customer trade changes a dealer's inventory level. If we denote the transition probability of state s_t to s_{t+1} as $\pi^{s_t s_{t+1}}$, then for three states, a total of nine transition probabilities can be derived:

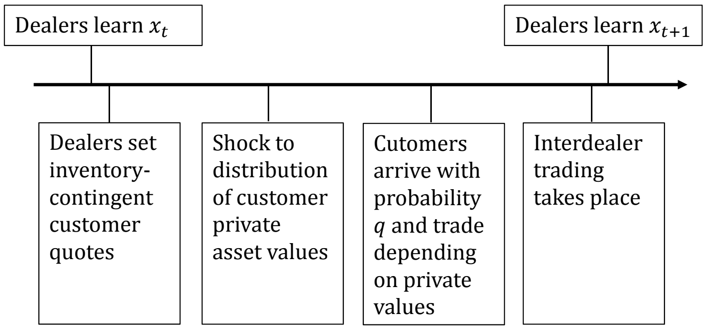


Figure 3.7: Timeline for the trading process in the model of Dunne et al. (2015)

$$M = \begin{bmatrix} \pi^{12} + \pi^{11} & \pi^{10} & 0 \\ \pi^{01} & \pi^{00} & \pi^{0-1} \\ 0 & \pi^{-10} & \pi^{-1-1} + \pi^{-1-2} \end{bmatrix}. \tag{3.30}$$

For example, the matrix element $\pi^{12} + \pi^{11}$ (first row and column) arises from two possible events. The dealer starts from an inventory level of 1. In the first case, he remains in this state, i.e. he does not conduct any trades in the customer market. The probability is denoted as π^{11}. In the second case, the dealer accepts a sell order and acquires an additional unit in the customer market. The probability is denoted as π^{12}. In the latter case, the dealer exceeds the maximum inventory level and has to offload the excess inventory in the interdealer market. In contrast (last row and column), the dealer starts from an inventory level of -1. He either remains in this state or he has to acquire one unit in the interdealer market. All other transition probabilities do not force the dealer to trade at the interdealer market.[10]

The transition probabilities depend on the standardized and state-dependent ask quotes $p^A(s)$ and bid quotes $p^B(s)$. Thus, the value function of the dealer can be stated as

[10] The authors assume the interdealer market to be a limit order market, in which no market participant has market-making obligations. This abstracts somewhat from the dealer structure we expect, but reflects the more and more competitive environment on the largest electronic interdealer platforms. For a discussion on this issue see Chapters 2.5 and 2.6.

$$V(s,x_t)=\begin{bmatrix} V(1,x_t)\\ V(0,x_t)\\ V(-1,x_t)\end{bmatrix}=(\max\left\{p^{\hat{A}}(s),p^{\hat{B}}(s)\right\})\beta\epsilon_t\left[\mathbf{MV}(s,x_{t+1})+\hat{\mathbf{\Lambda}}\right], \quad (3.31)$$

where ϵ_t is the expectation operator and $\hat{\mathbf{\Lambda}}$ represents the payoff given by

$$\hat{\mathbf{\Lambda}}=\begin{bmatrix}\hat{\Lambda}(1)\\ \hat{\Lambda}(0)\\ \hat{\Lambda}(-1)\end{bmatrix}=\begin{bmatrix}\left[p^{\hat{b}}-p^{\hat{B}}(1)\right]\pi^{12}+p^{\hat{A}}(1)\pi^{10}+rx_t\\ -p^{\hat{B}}(0)\pi^{01}+p^{\hat{A}}(0)\pi^{0-1}\\ -p^{\hat{B}}(-1)\pi^{-10}+\left[p^{\hat{A}}(-1)-p^{\hat{a}}\right]\pi^{-1-2}-rx_t\end{bmatrix}. \quad (3.32)$$

For example, the payoff in state $s=1$ includes the expected profit if a sell at the dealer's bid quote happens, $p^{\hat{b}}-p^{\hat{B}}(1)$, and if a purchase at the dealer's ask quote happens, $p^{\hat{A}}(1)$. Analogous explanations are possible for the other two states. The term rx_t captures the opportunity cost of capital for one unit of the asset with interest rate r.

The authors are able to show that the value function of the dealer is the discounted expected cash flow from his service of intertemporal intermediation in the customer market using the interdealer market for inventory control. They further show $V(-1,0)=V(1,0)<V(0,0)$, that is the dealer is in a more favorable position with a zero inventory because he is able to absorb customer trades without having to resort to the interdealer market. In contrast, if a dealer has an extreme inventory state, e.g. he is short (-1), he is not able to internalize a further customer buy order and instead is forced to buy in the interdealer market. Of course, this reduces his value function.

To determine a dealer's optimal price quotations in the customer market, first-order conditions are obtained by differentiating Equation 3.31 with respect to the bid and ask prices for each inventory state, that is $(p^{\hat{A}}(s),p^{\hat{B}}(s))$. The optimal bid and ask price quotations are

$$\begin{bmatrix} p^A(-1) \\ p^A(0) \\ p^A(1) \end{bmatrix} = \begin{bmatrix} \frac{1}{2d} \\ \frac{1}{2d} \\ \frac{1}{2d} \end{bmatrix} + \frac{1}{2} \begin{bmatrix} \frac{S}{2} \\ \overline{V} \\ -\overline{V} \end{bmatrix} \tag{3.33}$$

and

$$\begin{bmatrix} p^B(-1) \\ p^B(0) \\ p^B(1) \end{bmatrix} = \begin{bmatrix} -\frac{1}{2d} \\ -\frac{1}{2d} \\ -\frac{1}{2d} \end{bmatrix} + \frac{1}{2} \begin{bmatrix} \overline{V} \\ -\overline{V} \\ -\frac{S}{2} \end{bmatrix} \tag{3.34}$$

depending on the inventory state, the concavity parameter $\overline{V}$ (which embodies a dealer's value loss due to inventory constraints) and the spread in the interdealer market S.

Dunne et al. (2015) are further able to show that the dealers with extreme inventory positions are those who provide the interdealer market with the most competitive bid and ask prices. The spread in the interdealer market is therefore determined by the dealers with the most extreme inventory positions. Furthermore, they are able to show a potential market breakdown. A high interdealer spread comes along with higher rebalancing costs for the dealer, which results in less attractive quotes in the customer market. If it comes to a customer sell or buy order anyway, this speaks in favor of a shock to the fundamental value of the asset. Subsequent rebalancing in the interdealer market occurs for a more informative customer order flow, which leads to a further widening of the bid-ask spread. This implies that the interdealer bid-ask spread is given by the difference between this adverse selection loss and the benefit of rebalancing inventory. A narrow bid-ask spread implies both a low information asymmetry risk and a costly inventory rebalancing.

Figure 3.8 depicts two functions. The B2C graph represents the equilibrium schedule in the customer market. The dealer's value loss due to inventory constraints ($\overline{V}$) monotonically increases with the half-spread in the interdealer market. In other words, higher interdealer spreads make inventory rebalancing more costly. Thus, the optimal quotes in the customer market depend on the spread in the interdealer market, i.e. less liquid interdealer markets worsen the trading options in the customer market. The B2B function represents the equilibrium schedule in the interdealer market (B2B). It defines the competitive interdealer spreads for dealers who have a certain level of $\overline{V}$, i.e. the maximum benefit of limit order submission. The two intersections of the B2C and B2B graphs in Figure 3.8 fulfill equilibria conditions in both markets, but the authors show that only Z_L is stable.

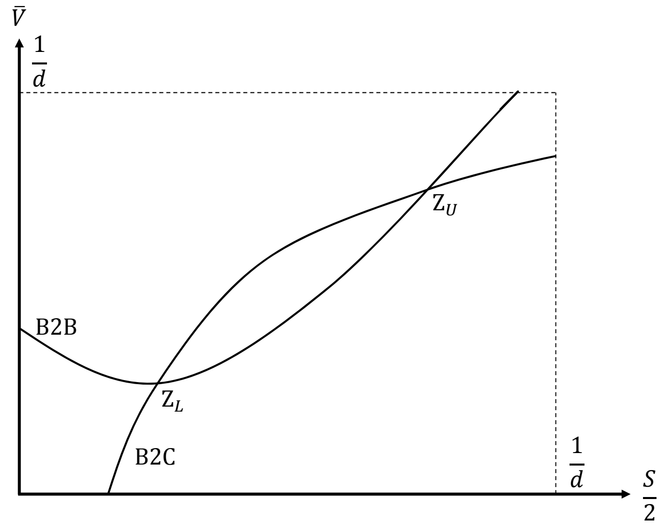


Figure 3.8: Optimal customer market quotes and competitive interdealer spreads in the model of Dunne et al. (2015)

3.6 Implications for the short-term price behavior in sovereign bond markets

If financial markets were informationally efficient, all relevant information would be priced in immediately. Changes in prices occur only if unanticipated information reaches the market. In this case, there is no serial dependence in successive price changes (aside from the serial dependence in expected returns). However, all financial markets are characterized by market frictions, which makes strategic behavior of market participants possible. This is the field of application of the market microstructure theory. The following section connects the aforementioned price implications of microstructure models with important peculiarities of sovereign bond markets.[11] This provides us with theoretically derived implications for the short-run behavior of sovereign bond prices.

The market microstructure literature argues that exchanging assets is associated with order processing costs for the dealer, such as costs of labor and capital needed to participate in the market. This is one of the reasons why market makers request compensation in the form of a positive bid-ask spread. In a stylized market, transactions occur either at the quoted bid price or the quoted ask price. If handling costs were the only source of the bid-ask spread and given that no new information arrives in the market, trade prices would tend to sway between bid and ask prices. After a sale at the bid price, the next price change would be zero or the spread. After a purchase at the ask price, the next price change would be zero or the negative spread. This implies negative serial dependence in successive market prices.

Sovereign bond markets are characterized by large trading volumes. Because handling costs are expected to be fixed in the short run, their relevance in dealer's decision of setting the spread should fall with trading volume. The same holds true for the increasing share of electronic trading in sovereign bonds, which should largely reduce the costs of service provision. The relation may be further weakened by the fact that dealers often make markets in many assets, which deliver new opportunities to amortize order handling costs.

Information-based microstructure models argue that making the market comes along with the risk of trading with investors who have superior information on the expected value of the asset. Since the market maker expects to systematically lose against insiders, he requests compensation in the form of a positive bid-ask spread. If asymmetric distribution of information were the only source of the bid-ask spread, trade prices would (instantly or gradually) reflect the private information revealed by insiders. Sales at the standing bid price may be a hint that the value of the asset will decrease. Depending on the cleanliness of the signal, this would cause a permanent fall in bid and ask prices. Purchases at the dealer's ask price may reflect that the asset is expected to be underpriced, which causes the dealer to raise his bid and ask prices.

[11] For a comprehensive overview of the structure of today's sovereign bond markets see Chapter 2.

The literature on the sources of the bid-ask spread is heavily weighted towards the role of information asymmetries in the market. This is comprehensible as the literature largely focuses on equity markets. In sovereign bond markets, however, it is not necessarily a natural assumption to expect private information to have an impact on asset prices. Prices of sovereign bonds are dependent on the term-structure of the underlying risk-free interest rates, which in turn, depend on macroeconomic fundamentals. Changes in macroeconomic factors, however, are expected to be public knowledge. In other words, private information about a bond's expected value is likely to play only a minor role in the variance in bid-ask prices and market liquidity. We expect the amount of payoff-relevant non-public information and the number of insiders in the market to be low in comparison to other financial markets.

However, two characteristics of sovereign bond markets speak in favor of asymmetrically distributed information, namely the multiple dealer structure and the two-tier structure of customer markets and interdealer markets. This allows market makers to have private information from their customer order flows, which then forms the basis for arbitrage profits in the interdealer market. Profits may also arise from the decentralized structure of sovereign bond markets, which results in a relatively low transparency in comparison to other financial markets.[12] This makes price adjustments due to information asymmetry likely.

Inventory-based microstructure models argue that holding asset inventory induces costs such as opportunity costs or the costs of carrying the price risk. Since dealers are interested in a desired portfolio structure, they adjust their quotes to induce equilibrating trades. From a dynamic perspective, a dealer lowers his quotes when he has a large inventory position and raises his prices when he has only a small inventory position. Sales at the bid price trigger falling price quotations to discourage additional sales and to encourage purchases. Purchases at the ask price lead to rising bid and ask prices to discourage additional purchases and to encourage sales. If inventory costs were the sole source of the bid-ask spread, trade prices and quotes

[12] This argument is somewhat questioned by the fact, that electronic trading platforms have largely increased price transparency in recent years. However, as Chapter 2.5 shows, the non-consolidated structure remains in many country markets. Dealers have possibilities to trade an asset on different platforms or bilaterally with other market makers.

would be negatively correlated over time.

Due to the fixed maturity of sovereign bonds, we are able to distinguish two types of investors: those who have a buy-and-hold strategy and those who trade the asset in the secondary market. The option of holding bonds until maturity reduces the supply of the asset available for trading purposes. This has a large impact on market liquidity, both in terms of trading intensity and bid-ask spreads. Since trading intensity is low in comparison to equity and forex markets, a dealer is confronted with relatively long waiting times for the arrival of orders. This makes it more difficult for a market maker to carry out inventory control activities. In other words, market-making obligations in sovereign bond markets are far more costly than in other financial markets, which cause the dealer to ask for a relatively large compensation.

This implication is contradicted by the large number of hedging instruments. Inventory risks in a specific bond can be hedged using another instrument. Possible options are to take an opposite position of a nearly identical security (i.e. a bond with quite similar yield movements), to acquire an offsetting position in the related futures contract or to use the possibility of borrowing or lending in the repo or lending markets. This results in a reduced necessity to rebalance the inventory position by adjustments in the bid and ask prices.

These insights lay the foundation for identifying the sources of the bid-ask spread in sovereign bond markets, which will be the focus of Chapter 4 and Chapter 5.

4 Decomposition of bid-ask spreads in European fixed-income markets

Abstract

This chapter examines the determinants and dynamics of liquidity in European fixed-income markets during the sovereign debt crisis. We recapitulate the market microstructure framework of Huang and Stoll (1997) and extend their spread decomposition model to capture intrinsic features of bond trading: interdealer inventory trading, order splitting, market-wide and country-specific trends, term-to-maturity effects as well as weekday and intraday patterns. Using high-frequency quote and trade data from the largest electronic interdealer platform for trading euro-denominated fixed-income securities, MTS, we find that trading on private information is rather less important in sovereign bond markets. Dealers only request compensation at the beginning of the trading week and the trading day when trading activity is fairly low and information asymmetries likely. Due to the local competitor EUREX and parallel price discovery processes, insider trading is relevant in the market for German bonds. Inventory control only plays a marginal role in dealers' decision of setting the bid-ask spread. It seems to be more likely that dealers actively trade and hedge imbalances. Market-wide trends in buying or selling are as important as the two traditional asset-specific spread components combined.

4.1 Introduction

For a short decade, sovereign bonds of eurozone member states were considered as almost free of risk, yields were low and spreads between them were small and stable. When the global financial crisis and subsequent troubles in government budgets gained center stage, both general public and academics started to focus on this asset class. The attention was not only on growing difficulties of some governments to issue new debt, but also on the evaporating market liquidity in sovereign bond trading. Since well liquid fixed-income markets are important for fiscal and monetary policy purposes, the present chapter tries to shed some light on the determinants and dynamics of investment behavior in government securities markets during the European sovereign debt crisis.

A financial market is denoted as liquid when market participants are able to immediately buy and sell assets in large volumes and with a small impact on prices.[13] From an empirical point of view, one of the most important indicators to measure liquidity is the bid-ask spread, i.e. the difference between best available buy and sell prices in the market. In government securities trading, which usually is organized in quote-driven markets, these prices are provided by selected market participants with market-making obligations. To better understand the dynamics of market liquidity, it is therefore necessary to understand the determinants of the quoting behavior of these market makers. The market microstructure approach thinks of the bid-ask spread as the costs and risks of service provision for which market makers want to be compensated. The literature generally distinguishes between three price-influencing components of the bid-ask spread, namely: order processing costs, inventory holding costs and information asymmetry costs. Their identification and quantification will be the focus of this chapter's research.

Since much of the market microstructure literature focus on equity markets, theoretical models are heavily weighted towards the role of trading on private information. The basic idea is that a dealer's bid-ask spread reflects a compensation against the risk of trading with better informed investors who otherwise are able to make arbitrage profits by buying assets that are underpriced and selling assets that are overpriced (see Chapter 3.4). Van Ness et al. (2001) compare a set of statistical frameworks to identify the importance of information asymmetries in trading stocks. They find a spread proportion of 18 to 67 percent. Lin et al. (1995) take trade size into account and find that the importance of information asymmetries varies from

[13] A comprehensive discussion on market liquidity is given by the Committee on the Global Financial System (1999, 2014).

20 percent of the spread for small trades to 63 percent for large trades. Madhavan et al. (1997) show that the relevance of private information is highest in the morning and decreases throughout the trading day. They argue that dealers learn about the true asset value during the day from the order flow. In contrast to stocks, we expect prices of government securities to depend foremost on publicly available information on underlying fundamentals. As a consequence, information asymmetries should play a minor role in trading sovereign bonds. However, in foreign exchange trading, which is expected to be as free from private information as sovereign bond trading, Osler et al. (2011) and Bleaney and Li (2016) find insider trading to be relevant. A potential source may be the non-consolidated market structure which allows parallel price discovery processes on different trading platforms. Furthermore, each dealer may have exclusive access to his own customer order flow, which may provide him with price-relevant information (Lyons, 1995, Cao et al., 2003).

The inventory holding component of the spread concerns dealers' asset and cash endowment. Providing a permanent trading opportunity may lead to unwanted inventory and cash positions. This induces opportunity costs and costs of carrying price risk (see Chapter 3.3). Research on single-dealer equity markets finds a spread proportion of up to 30 percent (Stoll, 1989, Huang and Stoll, 1997). The price impact of inventory holding is expected to increase with trading volume. Madhavan et al. (1997) show that inventory effects are manifested towards the end of the trading day due to increasing price risks associated with carrying inventory overnight. We expect that the multiple-dealer structure of European bond market trading is likely to reduce the relevance of inventory control. Dealers are able to actively trade unwanted inventory positions with other dealers. Correcting for the possibility of interdealer trading in the forex market, Bleaney and Li (2016) find inventory control to be irrelevant in setting the spread. Furthermore, in sovereign bond trading investors have a large choice in hedging instruments which also should reduce the necessity to trade inventory imbalances by adjusting bid and ask price quotations (Vitale, 1998).

Finally, the order processing component reflects compensation with respect to expenditures for service provision. This may be participation fees, salaries, information procurement and other administrative costs. George et al. (1991) find order processing costs to be the predominant spread component in equity markets. Lin et al. (1995) show that costs are relatively high for small trades and decrease with trade size. Since order processing costs are largely fixed and the average trade size is considerably larger in sovereign bond trading than in equity trading, we expect this cost component to be small as well.

Besides these traditional sources of the bid-ask spread, other components have been proposed in the literature. Relevant examples are noncompetitive pricing (Levin and Wright, 2004) and counterparty search costs in non-consolidated markets (Flood et al., 1998, 1999, Duffie et al., 2005). We expect, however, that in electronic trading environments and highly competitive markets this cost components should be small.[14]

Although these sources of the spread are well understood, their empirical identification and measurement remains challenging. Based on data availability, several forms of statistical models have been developed to link spread size and price dynamics to trading-specific factors. According to their decomposition approach the models can broadly be classified into covariance-based models (Roll, 1984, Choi et al., 1988, Stoll, 1989, George et al., 1991), vector autoregressive models (Hasbrouck, 1988, 1991) and trade indicator models (Glosten and Harris, 1988, Lin et al., 1995, Madhavan et al., 1997, Huang and Stoll, 1997). The statistical framework of Huang and Stoll (1997) has become one of the workhorse models in intraday spread decomposition. The model is one of the few that allows to decomposition of the bid-ask spread into all three traditional cost components. Furthermore, when adding minor restrictions the model coincides with several of the previous trade indicator and serial covariance models.[15] We use this model as our starting point. The statistical framework is, however, adjusted for single-dealer equity trading on the NYSE, which is in many respects different to electronic interdealer trading of government securities. We therefore adjust the model for important features of bond trading. We adapt the time-corrected version of the model from Henker and Wang (2006) and transfer the modifications for interdealer trading from Bleaney and Li (2016). We further control for block trading, market-wide and country-specific trends, term-to-maturity effects

[14] An extensive theoretical discussion of different spread components is provided in Chapter 3.
[15] See Huang and Stoll (1997, p. 1001f.) for a comparison of the framework to other models.

as well as weekday and intraday patterns.

For our empirical analysis, we make use of high-frequency quote and trade data from MTS, which is by far the largest interdealer market for trading European fixed-income securities.[16] The cleaned data set covers a large sample of 545 euro-denominated fixed-rate coupon and zero coupon bonds issued by the national treasuries of ten eurozone countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal and Spain. The sample covers 125 trading days from January 2 to June 28, 2013. This results in more than 40 million quote revisions and 74,802 executed trades.

The work in hand contributes to the existing literature by refining the decomposition model of Huang and Stoll (1997) with respect to fixed-income trading. Our bond-market model captures a set of important market features and largely improves the empirical performance of spread decomposition models in sovereign bond trading. Based on this statistical framework, we are able to test several market microstructure hypothesis and therewith gain insight into investment behavior of government securities dealers. Do they fear information asymmetries in the market—at least in times of crisis? How important are quote adjustments to control inventory when hedging and interdealer trading are possible? Are order handling costs a relevant spread component in today's highly competitive electronic trading environments? Are there any other price-influencing factors in times of large market uncertainty?

Our empirical results suggest that both the risk of information asymmetries and inventory holding play a significant but minor role in dealer's decision of setting the spread. Trading on private information is rather less important in sovereign bond markets since almost all price-relevant information on public issuers are publicly and simultaneously available to investors. If anything, protection against private information is relevant in the beginning of the trading day and the trading week, when trading activity is fairly low and the risk of meeting a better informed counterparty relatively high. We further find this effect for long-term bonds as well as for trading German securities. The latter is explainable by the local competitor EUREX, which

[16]For further information see Chapter 2.6.

causes parallel price discovery processes. Adjusting quotes for the reason of inventory imbalances seems to be an unrealistic investment option for bond dealers. Instead, they make use of interdealer trading or hedge their inventory positions. With respect to the term structure, inventory holding is only relevant for long-term bonds, which we explain by a large share of buy-and-hold investors, which makes active trading less frequent. Order processing costs are by far the most important spread component in interdealer sovereign bond markets. This result leaves a void, since traditional processing costs, such as for information procurement, salaries or technical equipment, are expected to be small with respect to average trading volumes. To shed some further light on the investment behavior of sovereign bond dealers in times of crisis, we extend our model for market-wide buying and selling trends. On average, about ten percent of bid-ask spread variations are explainable by this trend indicator which therewith is as important as adverse selection and inventory holding combined.

The remainder of this chapter is organized as follows: Section 4.2 delivers the theoretical background of our empirical model. We review the widely used decomposition model of Huang and Stoll (1997) and refine it for relevant features of sovereign bond trading. Section 4.3 discusses stylized facts of the European fixed-income market and the underlying data set. Further, the section presents the empirical approach and our estimation results. Section 4.4 summarizes and concludes.

4.2 Model framework

This section presents the two- and three-way spread decomposition model of Huang and Stoll (1997). Based on this, we develop a statistical framework that captures important features of sovereign bond trading, namely order splitting, interdealer trading of inventory, market-wide and country-specific trends, term-to-maturity effects as well as weekday and intraday patterns.

4.2.1 Basic model

The starting point of Huang and Stoll (1997) is the hypothesis that the trade price of an asset is a linear function of the bid-ask spread and the midpoint of the spread that prevail just before the transaction at time t. Formally, the relationship is given by

$$P_t = M_t + \frac{S}{2} Q_t, \tag{4.1}$$

where P_t is the transaction price, M_t is the quote midpoint, S is the (constant) bid-ask spread, and Q_t is a trade indicator variable which equals $+1$ for a buy order and -1 for a sell order. Thus, abstracting from any public information shocks that may blur the relationship, the trade price equals either the dealer's quoted ask price in the case of a buy order (quote midpoint plus half the bid-ask spread), or the bid price when it is a sell order (quote midpoint minus halt the bid-ask spread).

According to the inventory models of Stoll (1978) and Ho and Stoll (1981), a dealer's quotation depends not only on his assessment of the fundamental value of the asset but also on the degree of divergence from his desired inventory level (see Chapter 3.3). If we assume that a monopolistic dealer starts the trading day at his target level, $i = 1$, and all trades up until $t - 1$ are of equal size, then the sum of executed trades will exactly reflect the deviation from his ideal inventory position. Formally, the midpoint of his quotation is given by

$$M_t = V_t + \beta \frac{S}{2} \sum_{i=1}^{t-1} Q_i, \tag{4.2}$$

where V_t represents a dealer's expectation of the fundamental value of the asset and β is the proportion of the half-spread attributable to inventory holding costs. According to Equation 4.2, the mid-quote price differs from the fundamental value by $\sum_{i=1}^{t-1} Q_i$, which is the accumulated inventory from the market open until $t - 1$. Obviously, in the absence of any inventory holding costs, the mid-quote price would equal the dealer's estimate of V_t. Taking the first difference of Equation 4.2 gives

$$\Delta M_t = \Delta V_t + \beta \frac{S}{2} Q_{t-1}. \tag{4.3}$$

Equation 4.3 shows that the dealer's decision to adjust his quotation is a function of a change in his expectation of the fundamental value of the asset and the direction of the most recent order. Under the assumption of market efficiency, all the accumulated inventory from before $t-1$ is already priced in. Of course, V_t is a hypothetical construct, which neither the dealer nor any other market participant can clearly observe. The dealer is, however, aware that other market participants may be better informed about the fundamental value (see Chapter 3.4). To incorporate information asymmetry into the model, Huang and Stoll (1997) follow the argumentation of Copeland and Galai (1983) and Glosten and Milgrom (1985). As long as there are potential insiders in the market, the direction of the most recent trade may contain private information which affects the dealer's beliefs about the fundamental value. Formally, a change in the dealer's assessment of the fundamental value is given by

$$\Delta V_t = \alpha \frac{S}{2} Q_{t-1} - \alpha \frac{S}{2} [E(Q_{t-1}|Q_{t-2})], \tag{4.4}$$

where the conditional expectation of the trade indicator in $t-1$, given Q_{t-2} is known, can be rewritten as

$$E(Q_{t-1}|Q_{t-2}) = (1-\pi)Q_{t-2} + \pi(-Q_{t-2}) = (1-2\pi)Q_{t-2}. \tag{4.5}$$

The trade reversal indicator, π, represents the probability that the trade at $t-1$ is opposite in sign to the trade at $t-2$. When $\pi = 0.5$, the trade at time $t-1$ contains no predictable information. However, once we allow $\pi \neq 0.5$, the change in the fundamental value is given by

$$\Delta V_t = \alpha \frac{S}{2} Q_{t-1} - \alpha \frac{S}{2} (1-2\pi) Q_{t-2}. \tag{4.6}$$

The change in V_t reflects the private information revealed by the last trade (first term on the right hand side), excluding the information in Q_{t-1} that is not a surprise (second term). Taking this expectation into account, the change in the quoted mid-price is given by

$$\Delta M_t = (\alpha + \beta) \frac{S}{2} Q_{t-1} - \alpha(1-2\pi) \frac{S}{2} Q_{t-2}. \tag{4.7}$$

To estimate the model parameters we follow the procedure of Huang and Stoll (1997) and replace the constant bid-ask spread by observed time-varying spreads in the following way:[17]

$$\Delta M_t = (\alpha + \beta)\frac{S_{t-1}}{2}Q_{t-1} - \alpha(1 - 2\pi)\frac{S_{t-2}}{2}Q_{t-2} + \epsilon_t. \tag{4.8}$$

The weight of the inventory control component is represented by β while α is the proportion of the spread attributable to information asymmetries in the market. Accordingly, $(1 - \alpha - \beta)$ is the weight of all other factors influencing the spread, which include order processing costs, counterparty search costs and profits due to market imperfections.[18]

The decomposition model of Huang and Stoll (1997) is widely used since it is among the few models that allow separation of all three cost components. However, even in single dealer equity markets, for which the model is designed, the empirical performance is not always satisfactory. Among others, Clarke and Shastri (2000), Van Ness et al. (2001) and De Winne and Majois (2004) find estimates of α with a negative sign for more than half of their samples. According to market microstructure theory, however, the adverse information component cannot be negative as long as at least one market participant has superior information. One reason is that empirical studies often find trade reversal probabilities of $\pi < 0.5$, which implies positive serial correlation in order flows. A low value of π, however, leads to a systematic downward bias in α. In addition, positive covariance between consecutive orders contradicts theory on inventory holding in the sense that inventory would accumulate or diminish incessantly. Finally, this may result in dealer failure as discussed by Garman (1976).

[17]The complete model of Huang and Stoll (1997) is developed for changes in the transaction price. Formally, they combine the first difference of Equation 4.1 and 4.8, so that

$$\Delta P_t = \frac{S}{2}Q_t + (\alpha + \beta - 1)\frac{S}{2}Q_{t-1} - \alpha(1 - 2\pi)\frac{S}{2}Q_{t-2} + \epsilon_t,$$

where the spread S is estimated as a constant value over time. We use the time-varying effective spread and estimate α and β directly from Equation 4.8.

[18]Estimating the model without the second term on the right hand side, i.e. focusing solely on the direction of the last order Q_{t-1} delivers us the two-way decomposition model of Huang and Stoll (1997). In this reduced form α and β can only be estimated together and a distinction between inventory holding and adverse selection is not possible. In accordance with Huang and Stoll (1997), we refer to the combined parameter as λ.

Henker and Wang (2006) show that timing misspecifications also contribute to the poor performance. The choice of timing for the spread in Equation 4.8 is simply motivated by the timing of the respective trade indicator variables Q_{t-1} and Q_{t-2}. Henker and Wang (2006) argue, however, that the timing of the second spread should be determined by the timing of the unexpected part of the order flow in $t-1$, which cannot be explained by Equation 4.5.[19] This results in

$$\Delta M_t = (\alpha + \beta)\frac{S_{t-1}}{2}Q_{t-1} - \alpha(1-2\pi)\frac{S_{t-1}}{2}Q_{t-2} + \epsilon_t, \tag{4.9}$$

where the spread in the second term is now S_{t-1} instead of S_{t-2}. To make things clearer, consider $S_{t-1} = S_{t-2} + \Delta S_{t-1}$, then Equation 4.9 can be re-written as

$$\Delta M_t = (\alpha + \beta)\frac{S_{t-1}}{2}Q_{t-1} - \alpha(1-2\pi)\frac{S_{t-2}}{2}Q_{t-2} - \alpha(1-2\pi)\frac{\Delta S_{t-1}}{2}Q_{t-2} + \epsilon_t. \tag{4.10}$$

Equation 4.8 omits the third term, which leads to a downward bias in the estimated α (and an upward bias in the estimated β). Since Henker and Wang (2006) are able to show that the corrected model removes over half of the negative adverse selection estimates compared to the original specification, we will reproduce their correction and refer to it as the "time-corrected model".

4.2.2 Model adjustments for sovereign bond trading

The model of Huang and Stoll (1997) is specified for a single market maker. The secondary market for sovereign bonds, however, is a multiple dealer market with a large share of interdealer trading. This gives liquidity suppliers a new possibility to adjust their inventories by actively placing orders with other dealers. For the foreign exchange market, which is also a multiple dealer market, Lyons (1997) and Evans and Lyons (2002) denote this type of repeated inventory offloading between dealers as "hot-potato" trading. Instead of a negative serial correlation of the order flow, as assumed by Huang and Stoll (1997), the trade direction in the market will tend to be positively correlated over time. For instance, after a buy order at the ask-price of

[19] The unexpected part of the order flow can formally be expressed as $u_{t-1} = Q_{t-1} - (1-2\pi)Q_{t-2}$.

a dealer, he will not primarily raise his prices to induce an equilibrating sell order but actively buy back the asset from another dealer in the market. This second method is more efficient because a dealer can shift inventory back to the target level immediately and surely (King et al., 2013). In addition to interdealer trading, sovereign bond dealers have a large set of instruments to hedge inventory imbalances. They can borrow or lend the same asset in the repo or lending markets, they can hold the opposite position of another bond with nearly identical characteristics, or they can offset the position with one in the related futures contract (Gravelle, 2002). By implication then, we expect the relevance of inventory holding costs in setting the bid-ask spread is overestimated by the model specifications above.

Up until now, we have assumed that the sum of all past trades represents the aggregate inventory imbalance in the market, $\sum_{i=1}^{t-1} Q_i$. This relationship is true as long as there are only trades between one single dealer and his customers. However, the dataset in use focus exclusively on interdealer trades. Thus, the sum of all past trades does not reflect inventory imbalances but "hot-potato" trading between dealers. Each dealer tries to rebalance his unwanted inventory position by actively placing orders with other dealers.[20] We follow the argumentation of Bleaney and Li (2016) and redefine the relationship as follows:

$$Z = k_1 \sum_{i=1}^{t-1} Q_i, \tag{4.11}$$

where $k_1 \geq 1$. Total interdealer trades, Z, exceed the aggregate inventory imbalance by a factor of k_1, which is a measure of the efficiency of imbalance re-distribution in the market. When $k_1 = 1$, the redistribution is at its most efficient. The result would equal the case of the Huang and Stoll (1997) model. The larger k_1 is, however, the more interdealer trades are necessary to remove inventory imbalances in the market.

Besides the efficiency of interdealer trading, the authors distinguish between a tolerable and intolerable part of unwanted inventory. The former is the part of unwanted inventory for which the dealer is able to directly trade with another dealer at current standing quotes. This is the active method to control inventory when interdealer trading is possible. Only the latter intolerable part of unwanted inventory

[20]For a formal discussion see the Appendix of Bleaney and Li (2016).

causes the dealer to adjust his bid and ask prices to attract an order flow in the opposite direction. The inventory level of dealer d at time t can formally be expressed as

$$Q_{t-1,d} + k_2 \sum_{i=1}^{t-2} Q_{i,d}, \tag{4.12}$$

where $0 < k_2 < 1$. A dealer's inventory level is the sum of the most recent order and the intolerable part of unwanted inventory from previous periods. k_2 is a measure of dealer d's ability to keep intolerable inventory close to zero. When $k_2 = 0$, the dealer is able to get rid of unwanted inventory completely through active trading. When $k_2 = 1$, the dealer cannot eliminate inventory actively, which leads to the same results as the Huang and Stoll (1997) model.

If there are N identical dealers in the market, the cumulated incoming order of an average dealer is

$$k_1 Q_{t-1} + \frac{1}{N} k_1 k_2 \sum_{i=1}^{t-2} Q_i. \tag{4.13}$$

If we assume that $N = k_1 = k_2 = 1$, i.e. the market consists of only one dealer, which makes inventory redistribution and active trading obsolete, Equation 4.13 reduces to the inventory holding premium postulated by Huang and Stoll (1997). Otherwise, we can rewrite Equation 4.2 as follows:

$$M_t = V_t + \beta \frac{S}{2} \left[k_1 Q_{t-1} + \frac{1}{N} k_1 k_2 \sum_{i=1}^{t-2} Q_i \right]. \tag{4.14}$$

Taking the first-order difference gives

$$\Delta M_t = \Delta V_t + \beta \frac{S}{2} k_1 Q_{t-1} + \beta \frac{S}{2} \left(\frac{k_1 k_2}{N} - k_1 \right) Q_{t-2}. \tag{4.15}$$

The difference to the Huang and Stoll (1997) decomposition model is that inventory control influences the mid-quote price now through the two most recent orders. Under the assumption that information asymmetry is handled as before, the change in the quoted mid-price is given by

$$\Delta M_t = (\alpha + k_1\beta)\frac{S}{2}Q_{t-1} - \left[\alpha(1-2\pi) + \beta\left(k_1 - \frac{k_1 k_2}{N}\right)\right]\frac{S}{2}Q_{t-2} + \epsilon_t. \qquad (4.16)$$

From an empirical point of view, neither the efficiency in inventory redistribution nor a dealer's ability in actively getting rid of unwanted inventory is directly observable in the data. With respect to the multiple dealer structure of sovereign bond markets, however, k_1 and k_2 deliver us an economically reasonable range of cost component weighting. When $N = k_1 = k_2 = 1$, the model equals the Huang and Stoll (1997) specification in Equation 4.8. Since actively trading unwanted inventory is not possible, this represents the upper boundary of the inventory component.

When there are many dealers in the market, $N = \infty$, imbalance trading is efficient, $k_1 = 1$, and each dealer is able to actively get rid of his unwanted inventory position, $k_2 = 0$, the model becomes

$$\Delta M_t = (\alpha + \beta)\frac{S_{t-1}}{2}Q_{t-1} - [\alpha(1-2\pi) + \beta]\frac{S_{t-2}}{2}Q_{t-2} + \epsilon_t. \qquad (4.17)$$

This represents the lower boundary of the inventory component. We refer to this model specification as the "interdealer model"

Correcting Equation 4.8 for both, time inconsistencies and interdealer trading, delivers our "bond-market model". Formally, this results in

$$\Delta M_t = (\alpha + \beta)\frac{S_{t-1}}{2}Q_{t-1} - \alpha(1-2\pi)\frac{S_{t-1}}{2}Q_{t-2} - \beta\frac{S_{t-2}}{2}Q_{t-2} + \epsilon_t, \qquad (4.18)$$

which we expect to suit best the market structure of sovereign bond trading. We extend the model framework to capture market-wide and country-specific trends, term-to-maturity effects as well as weekday and intraday patterns.

The global financial and economic crisis has shown that market-wide trends might be a relevant factor in setting the spread.[21] To incorporate this aspect into the model framework, we follow Henker and Martens (2010) and include a commonality variable,

[21] The relevance of common components to returns, order flow and liquidity was studied first by Chordia et al. (2000), Hasbrouck and Seppi (2001) and Huberman and Halka (2001).

Q^M, which considers the direction of the most recent trades in all sovereign bonds of our sample. In this way, Q^M proxies market-wide buying and selling pressure. The variable equals +1 (−1) if the number of ask (bid) trades within the half-hour interval around each trade is statistically larger than the number of trades at the bid (ask). Otherwise, Q^M takes the value zero.

Another peculiarity of trading this asset class is its fixed term-to-maturity. We therefore decided to generalize our model for three maturity buckets. We expect that in times of uncertainty, as in our sample period, the market shows "flight-to-liquidity"-effects, i.e. many investors move towards more liquid short-term bonds and trading in long-term assets becomes less frequent. Beber et al. (2009) and Goyenko et al. (2011) find a significantly steeper liquidity term structure during times of heightened uncertainty. For market participants with market-making obligations in long-term assets, this increases the probability of trading with better informed investors, which should lead to a larger estimated compensation for adverse selection. Infrequent trading increases further the risk of unfavorable price movements and thus, inventory holding costs. For the U.S. and European bond markets, Dufour and Nguyen (2008) and Engle et al. (2012) find an impact of the term structure with respect to bid-ask spreads, frequency of quote updates, quoted depth, and price volatility.

Finally, we control for weekday and intraday periodicity. During the trading day bid-ask spreads often show a reversed J-shaped (McInish and Wood, 1992, Abhyankar et al., 1997, Hussain, 2011) or U-shaped (Brock and Kleidon, 1992, Ahn and Cheung, 1999, Ahn et al., 2002) pattern, which implies that the spread is wide at the open, small through the day and rises (slightly) at the close. We expect the same U-shaped pattern for the spread as the week progresses. We expect that both the beginning of the trading day and the trading week show opening effects due to the fact that the European bond market opens 45 minutes earlier compared to European equity markets. We further expect a widening of the spread at the end of the trading day and trading week because this is the time when most dealers have fulfilled their quoting obligations and/or are concerned about carrying inventory overnight or over the weekend. With respect to the cost components of a dealer's bid-ask spread, Foster and Viswanathan (1993) and others show that at equity markets order processing costs have little variation over the trading day while information asymmetry costs are high at both open and close. Concerning inventory holding costs, we expect a relatively low trading intensity in the beginning of both the trading day and trading week, which may lead to higher inventory premiums.

4.3 Empirical evaluation

4.3.1 Data description and preparation

The intraday data used in this study stem from MTS Cash, which represents the largest electronic interdealer platform for trading European sovereign bonds. With a market share of more than 70 percent of electronic trading and an average daily turnover of over EUR 100 billion, MTS Cash is the leading interdealer secondary market for euro-denominated fixed-income securities. The trading system is fully automated and works as a quote-based electronic limit order market.[22]

The data provide details of marketable quotes and executed transactions which are recorded with millisecond time stamps. For each bond we have information on trade prices, quantities as well as the direction of the trade. While in most trade-indicator studies the Lee and Ready (1991) algorithm[23] is used to roughly classify trades as buyer- or seller-initiated, we are able to precisely assess which market side triggered the transaction. In addition, the data contain every submitted quote revision that changes the three best bid/offer prices and/or quantities in the market.[24]

One peculiarity of the MTS interdealer platform is its two-tier structure. MTS Cash is divided into a centralized European platform for trading benchmark bonds and domestic market platforms for trading the whole yield curve of the respective country. The marketplaces are not formally linked and parallel quoting of the

[22]For further details see Chapter 2.6.

[23]Simply put, a transaction is initiated by a buyer (seller) when the trade price is higher (lower) than the quote midpoint that was in force directly before the transaction. This algorithm has proved to be sufficiently efficient but misclassification may still be a problem (see Theissen, 2001).

[24]The reported quotations in the limit order book establish the market but are not necessarily from the same market maker. They represent a synthetic market spread between the three highest bid prices and the three lowest ask prices and can be interpreted as the price of liquidity.

same bond on two platforms is possible. We decided to consider quote and trade data from both markets for two reasons. First, according to Cheung et al. (2005) as well as Caporale and Girardi (2011), the domestic market and the European reference market constitute essentially one single venue. Pelizzon et al. (2013) report that market participants are provided with price updates from both venues on a consolidated screen. Second, even if quotes and transactions are anonymous, the metadata indicates that for most bonds the number of participating market makers is the same in both marketplaces. This speaks in favor of most dealers participating in both platforms, which should ensure price consistency. Not considering one of the two would increase the risk of disregarding relevant parts of the price discovery process.[25]

Another issue that needs discussion is the matching of trades and quotes. The Huang and Stoll (1997) approach needs both information on quotes and transactions. As in most studies, however, we do not know which trade results from which preceding bid and ask price quotations. We decided to pair each trade with the last entry in the limit order book that were in force up to a millisecond before the transaction. This approach slightly differs from Huang and Stoll (1997) who use a quote delay of five seconds. We argue that in today's electronic trading environments the automated execution of trades happens as soon as a hitting order or matching quote reaches the market. This is in line with Pelizzon et al. (2013) who report that quotes are suspended one millisecond before the recorded time of arrival of the order on the MTS platforms.

A final issue is that of block trading. Due to the electronic trading environment, order-specific transaction costs have declined significantly in recent years. This makes order splitting and trading en bloc more attractive. Large trading positions may be divided into small subsequent orders to reduce price impacts or to disguise private information. Furthermore, if an arriving market order is larger than the best quoted position, the remaining part of the order may hit the second best quotation in the order book. Conversely, a large quoted position may be executed against various

[25] A more detailed description of the MTS market microstructure is provided by Dufour and Skinner (2004) and Cheung et al. (2005).

incoming market orders. While theory refers to orders that generate trades, the data available most often report only executed trades. This makes the identification of block trading hardly feasible. Huang and Stoll (1997) and others suggest clustering sequential transactions with no intervening quote adjustments into a single trade. Fortunately, we are able to refine this procedure. The MTS data set provides an identification number that determines whether a same order originated one or more trades. This largely reduces the problem of "overcorrection". Taking this information into account, we collapse all uninterrupted sequences of conjugated trades with the same identification number that take place at the same price and on the same side of the market. The problem remains that subdivided orders are not necessarily executed in a row without intermediate transactions or quote revisions from other market participants. This is aggravated by the common practice of trading at slightly increasing or decreasing prices to make full use of the depth of the order book. Expanding the clustering procedure to these peculiarities of modern trading would significantly reduce our data set and raises the risk of lumping independent trades together. We therefore remain with the bunching procedure described above.

The analysis is confined to regular transactions and quotes of 545 euro-denominated fixed-rate coupon and zero coupon sovereign bonds issued by the national treasuries of ten European countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal and Spain. The sample covers 125 trading days from January 2 to June 28, 2013. Each trading day starts at 8:15am and finishes at 5:30pm (CET/CEST). As a result, the data set covers more than 40 million quote revisions resulting in 74,802 executed trades.

According to Table B.1, Italian bonds are by far the most traded securities in our sample. 48 percent of all transactions stem from trading activities in Italian treasuries. This stems from the large amount of Italian public debt as well as monitoring requirements of the Italian Treasury, which leads MTS to represent almost 100 percent of Italian sovereign bond trading. In contrast, the markets for Irish and Portuguese securities are the smallest ones in our sample. Despite its benchmark status in Europe, trading of German sovereign bonds is relatively low on the MTS platforms (solely 5 percent of all sample trades). Reasons are the local competitor EUREX as well as the existence of highly-liquid futures contracts as an alternative venue to build exposure to German yields. The buy-sell ratio indicates that, on average, as many buyer-initiated trades as seller-initiated trades took place. This slightly differs between countries, with clearly more buyer-initiated trades than seller-initiated trades of Portuguese bonds and the opposite ratio with regard to Finnish and Dutch securities. This speaks in favor of flight-to-quality effects during the sample period. On average, 39 institutional investors participate on the domestic and European trading platforms and about half of them act as market makers.

With regard to maturity, 47 percent (32 percent, 21 percent) of all securities have a short (intermediate, long) term-to-maturity. Table B.2 shows that trading activity is highest for bonds with a short term-to-maturity as well as in the middle of the trading week. During our sample period each bond is traded, on average, 137 times with low trading activity for Irish bonds and high activity for Italian treasuries. A mean of 598 trades took place every trading day. This results in one trade every minute which is fairly low in comparison to trading intensities in equity and forex trading. The peculiarity of bond trading is the large traded quantities. The transaction size ranges from EUR 0.5 to 120 million with an average quantity of more than six million euro per trade. This leads to an average daily turnover of more than EUR 3.6 billion in our sample. The daily turnover is lowest for Irish securities (about EUR 8.6 million) and highest for Italian bonds (approx. EUR 1.4 billion). All trades in our sample reflect more than EUR 450 billion of market value. With regard to prices, bonds of nine out of ten countries are traded regularly above par value. Only Portuguese securities are traded, on average, slightly below par. Trade prices are highest for long-term bonds and small trades sizes as well as in the middle of the week and the end of the trading day.

Besides information on trades, the data set provides details on the three best bid and ask prices.[26] An intuitive measure of market makers' trading costs is the quoted bid-ask spread, i.e. the difference between the lowest ask price and the highest bid price on the screen. Due to the fact that the number of quotes and executed trades

[26] While 43 percent of all quotes are submitted to the EuroMTS platform, only 8 percent of trading activity takes place on the pan-European venue.

is out of proportion, however, the quoted spread includes periods of little trading activity. This results in a relatively large average quoted spread of EUR 0.70. In addition, a significant share of trades takes place inside the posted quotes. A more accurate indication of trading costs is therefore the effective spread

$$S_t^{effective} = 2 * |P_t - M_t| \,, \tag{4.19}$$

which we make use of in the empirical analysis. The effective spread is calculated as twice the absolute difference between the trading price at the time of t and the mid-quote price valid up to a millisecond before the trade. The effective spread is, on average, EUR 0.17 with the lowest average value for Belgian bonds (0.04) and the highest values for Irish and Portuguese securities (0.51 and 0.48, respectively). The market is most liquid for short-term bonds and large trade sizes. On Wednesdays and Thursdays the average effective spread is up to five cents smaller than in the beginning and in the end of the trading week (see Figure B.1). According to Figure B.2, the market is most liquid in the middle and end of the trading day. This U-shaped intra-week and reversed J-shaped intra-day periodicity is even more obvious with regard to the quoted spread, which is best explainable by thousands of fewer trades on Mondays and Fridays as well as in the morning of the trading day.

4.3.2 Estimation procedure

Following Huang and Stoll (1997) and others, we use the GMM procedure to estimate the two-equation system. This ensures a common estimation framework and enhances the comparability of the results. The method is often used because of its very weak distributional assumptions. The procedure easily accommodates conditional heteroskedasticity of an unknown form and serial correlation in the residuals.

The basic Huang and Stoll (1997) trade indicator model (Equations 4.5 and 4.8) is implemented in the GMM structure by the vector function:

$$f(x_t, \omega) = \begin{bmatrix} u_t Q_{t-2} \\ \epsilon_t S_{t-1} Q_{t-1} \\ \epsilon_t S_{t-2} Q_{t-2} \end{bmatrix}, \tag{4.20}$$

where $u_t = Q_{t-1} - (1 - 2\pi)Q_{t-2}$ and $\omega = \begin{bmatrix} \pi \alpha \beta \end{bmatrix}'$ is the vector of parameters of interest. The basic model implies the moment conditions $E[f(x_t, \omega)] = 0$. All other model specifications are implemented in the same manner. With three parameters (π, α, β) to be estimated, the models are exactly identified.

4.3.3 Empirical results

Table B.3 presents the regression results of all model specifications for the whole sample of bonds as well as subdivided by issuer country.

Concerning the results of the two-way decomposition model, trade-specific factors in $t-1$ seem to play a significant but minor role in dealer's decision of adjusting his bid and ask price quotations. λ accounts for a spread proportion of 7.7 percent, on average. This is low in comparison to empirical results for equity and forex trading. The results underpin our expectation that almost all price-relevant information on public issuers are publicly and simultaneously available to investors. Thus, the risk of trading with insiders seems to be rather less important in sovereign bond markets. Concerning the second component of λ, inventory holding costs, market makers seem to make use of the possibility to actively trade inventory imbalances with other dealers instead of adjusting their quotation to initiate an equilibrating market order. We will discuss this in more detail within the scope of the bond-market model. With respect to the issuing country, λ is largest for Austrian and German sovereign bonds (18 and 20.7 percent, respectively) and smallest for Belgian securities (3.8 percent). This may be motivated by a higher trading frequency of Belgian bonds which reduces the time between transactions.

The empirical results of the three-way spread decomposition model of Huang and Stoll (1997) show that the probability of a trade reversal is fairly low in our sample. Despite our improved cleaning procedure for block trading, the trade direction changes, on average, only in one third of all cases. The value of π ranges from 27.7 percent for Irish bonds to 35.6 percent for Belgian assets. The positive serial correlation in the order flow gives rise to a well-documented upward bias of the inventory holding component β and a downward bias of the information asymmetry component α. Table B.3 shows that the α-coefficient is negative and insignificant for almost all country samples. From a theoretical point of view, this is elusive since a dealer's compensation for insider trading cannot be negative as long as at least one investor possess superior information on the asset. Even if the inventory holding component is positive and statistically significant, averaging 10.4 percent of the spread over all bonds, the results of this baseline regression should be interpreted with care. In conformity to the empirical literature, we conclude that the single-dealer model is not suitable for analyzing the effective spread on European sovereign bond markets.

As discussed above, we firstly correct for time inconsistencies in the model as revealed by Henker and Wang (2006). Nevertheless, the core problems of the baseline model remain. On average, α is negative for half of the issuer countries and β is expected to be overestimated with an average spread proportion of nine percent. We conclude that the regression results are not reliable either.

Reality suggests the assumption that market makers in multiple dealer markets do not wait for an incoming order to equilibrate their inventory but actively trade imbalances by hitting quotes of competing dealers in the market. We proceed on the assumption that this investment behavior plays an important role on the interdealer platform of MTS. On almost all country platforms a large share of market participants has market-making obligations, which speaks in favor of active inventory trading between dealers. By implication then, the spread weight of inventory holding costs is overestimated by both preceding model specifications. However, the results of the interdealer-corrected (but not time-corrected) model of Bleaney and Li (2016) seem to "overcorrect" for the inventory bias. The inventory holding component is now negative for almost all countries and the information asymmetry component is relatively large, averaging -4.7 percent and 12.7 percent of the spread, respectively. We follow the argumentation of the authors. When the model of Huang and Stoll

(1997) represents the upper boundary of the inventory component and the lower boundary of the adverse selection component, then the interdealer specification represents the opposite. As with the model specifications before, the estimated coefficients of the interdealer model should be interpreted with care.

Considering both modifications simultaneously, i.e. correcting for time inconsistencies in the baseline model and modifying for interdealer trading, delivers our bond-market model. We expect that this model specification best suits the bond market structure. We are able to show that both classic cost components of the bid-ask spread, namely information asymmetry and inventory holding, are less important in sovereign bond trading than they are in equity or corporate bond markets. According to Table B.3, the estimation results confirm the fairly low importance of both components as shown before by the combined estimator λ in the two-way decomposition specification. Both components seem to play a significant but minor role in a dealer's decision of setting the spread. On average, a proportion of 5.9 percent of the spread is related to the risk to trade with better informed investors. The importance of private information ranges from 14.3 (12.9) percent for Austrian (German) bonds to -0.9 percent for Irish bonds. Thus, for Austrian and German securities the risk of insider trading is evaluated up to three times larger than on average. As discussed above, this may be due to higher local platform competition in bond trading, which causes parallel price discovery processes. The result for Irish bonds show that negative values for α may still occur, but the problem is largely reduced. Furthermore, one has to bear in mind that for Ireland the number of observations is quite small. We conclude that payoff-relevant insider information about the fundamental value of an asset play, on average, only a minor role in the investment behavior of bond market dealers. The price of sovereign bonds seems to depend largely on macroeconomic factors about which market participants are equally well informed. In addition, today's electronic trading systems have largely increased the degree of centralization, which makes the best bid and ask prices for an asset more easily available on a consolidated screen. This further reduces the possibility of trading on private information.

Besides the information asymmetry component we are able to separately identify the impact of inventory holding costs in setting the spread. For all 545 bonds in our sample, the component averages to 2.1 percent of the bid-ask spread. The share is largest for Irish securities which results from the interaction with the negative value for α. Abstracting from this, German and Austrian bonds show the largest significant inventory component, averaging 6.9 and 4.1 percent of the spread, respectively. For all the other securities in our sample, setting quotes and waiting for an equilibrating incoming order seems to not be a realistic investment option. Instead, dealers make use of interdealer trading of inventory imbalances, as they is by far more immediately and surely. Gravelle (2002) invokes another explanation for the low importance of inventory holding costs in government bond trading in comparison to equity or corporate bond trading. There are many more financial instruments available to hedge sovereign bond inventories. For instance, market makers can hold the opposite position of a nearly identical security, they can borrow or lend the same asset in the repo or lending markets, or they can offset the inventory position with one in the related futures contract.

The low estimated values for both information asymmetry costs and inventory holding costs indicate that order processing costs seem to be the most important influencer on prices. As in the two-way decomposition specification an average of 92 percent of the effective spread is related to costs associated with order handling. This result needs further research in the future. What we know is that market-making competition is relatively high on almost all national and European venues of MTS. Thus, monopoly rents should carry no large weight. Further, we expect that counterparty search costs should play only a minor role because MTS is by far the largest and most consolidated market for trading European sovereign bonds. In some cases, like the Italian market, MTS is even the only authorized trading platform. Finally, classic order processing costs, such as for information procurement, salaries or technical equipment should be small with respect to the large average trading volume. To shed some light on the unexplainable part of the spread, we add a market-wide trend indicator to our bond-market specification. The indicator captures the general buying or selling pressure in the whole market. According to Table B.3, the regression results for both the adverse selection and inventory holding component are robust. An additional spread proportion of about 8.6 percent is now attributed to γ, the indicator for market-wide trends. This means that after a trade, a dealer changes his quotation not only due to asset-specific developments like inventory imbalances, private information releases and accrued order-processing costs, but also due to market-wide developments. When there is a buying (selling) pressure over all MTS platforms, a representative dealer answers by raising (reducing) his price quotations.

Finally, Table B.4 presents the regression results of the bond-market model with respect to different bond and trading characteristics. The probability of a trade reversal shows neither any periodicity nor does it depend on the term-to-maturity of an asset. However, the maturity date of a bond seems to play an important role in setting the spread. The trade-specific effective spread of bonds with a term-to-maturity of more than 10 years is bigger by half of the spread of medium-term bonds and about six times as large as the spread of assets with a short term to maturity (see Table B.2). Concerning the spread components, adverse selection is largest for long-term bonds. Asymmetric information accounts for 7.6 percent of the spread while it is not statistically significant for short-term bonds. The results are less clear for the inventory component, which accounts for about 2 percent over all maturity classes. Nevertheless, only for trading long-term bonds the inventory component is statistically significant. One reason may be that with respect to long-term bonds many investors follow a buy-and-hold strategy which makes active trading less frequent (see Table B.2). The impact of market-wide trends in setting the spread is largest for long-term bonds.

The necessity of a dealer to get compensated against the risk of insider trading seems to depend on both the weekday and the time of the day. The importance of information asymmetry is largest on Mondays as well as in the morning of the trading day. In both cases, about 11 percent of the bid-ask spread is attributable to insider trading. This is the time when trading activity is fairly low and the risk of trading with better informed investors relatively high. We explain this by differences in information procurement during weekends and outside trading hours. In contrast, the requested compensation for inventory holding costs shows no clear periodicity.

The component is statistically significant only on Tuesdays and between 10:00am and 4:00pm of the trading day. This slightly contradicts our assumption of potentially higher inventory holding costs at the end of the trading day and the trading week. The estimated coefficient γ shows the same periodicity as the information asymmetry component. Market-wide trends seem to be most important on Mondays (17.4 percent) and at the beginning of the trading day (11.3 percent). This may be caused by different levels of information on "global" developments, which make dealers more concerned about the trading behavior of other market participants.

4.4 Conclusions

Well-functioning sovereign bond markets play a key role in the maintenance of a stable financial system. The European sovereign debt crisis and the repeated sell-off of European government securities drew attention, however, that market liquidity can evaporate quickly. A deeper understanding of the determinants and dynamics of liquidity in fixed-income markets is therefore urgently needed.

The vast majority of sovereign bond trading occurs through quote-driven over-the-counter markets in which a limited number of institutional investors fulfill market-making obligations by posting executable bid and ask prices. Thus, market liquidity hinges in large part on the capacity and willingness of a few market participants. Against this background, we aimed to shed light on the investment behavior of these dealers in European fixed income markets in times of crisis.

We refined the workhorse model of Huang and Stoll (1997) and capture therewith important features of sovereign bond trading at the largest electronic trading platform for euro-denominated sovereign bonds, MTS. Our empirical results suggest that both the risk of information asymmetries and inventory holding play a significant but minor role in a dealer's decision of setting the spread. Trading on private information is rather less important in sovereign bond markets since almost all price-relevant information on public issuers are publicly and simultaneously available to investors. If at all, private information is relevant at the beginning of the trading week and the trading day. This is the time when trading activity is fairly low and the risk of meeting a counterparty with insider information relatively high. We further find some private information effects for long-term bonds as well as for trading German securities. The latter is explainable by the local trading platform EUREX, which makes parallel price discovery processes likely. Adjusting quotes for the reason of inventory imbalances doesn't seem to be a realistic investment option for dealers in this market segment. Instead, they make use of interdealer trading and hedging of inventory positions. With respect to the term structure, inventory holding is only relevant for long-term bonds, which we explain by a larger share of buy-and-hold investors, which makes active trading less frequent. The low estimated values for both traditional parameters indicate that order processing costs are by far the most important spread component in interdealer sovereign bond markets. This result leaves a void, since the order processing component represents a conglomeration of different cost-causing factors. To shed some light on this part of the spread, we extend our model for market-wide buying and selling trends. On average, about ten percent of the bid-ask spread is explainable by this component, which thus is as important in influencing market liquidity conditions as information asymmetry and inventory holding combined.

B Appendix

Figure B.1: Average effective spread (weekday)

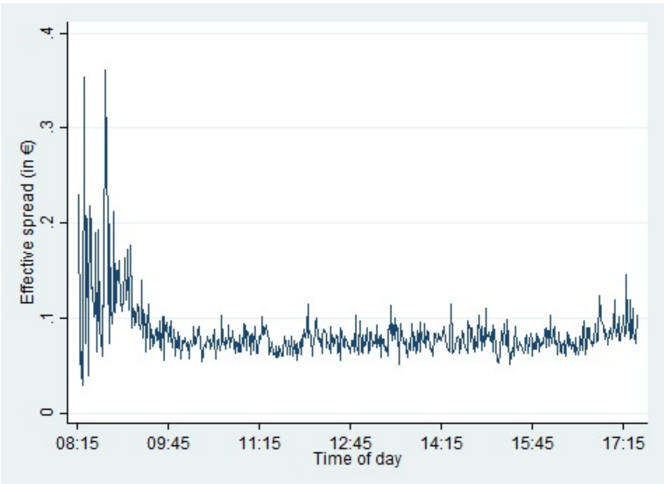


Figure B.2: Average effective spread (intraday)

Table B.1: Descriptive statistics (by issuer)

Category		AT	BE	DE	ES	FI	FR	IE	IT	NL	PT	Total
Bonds	#	21	59	79	80	14	133	15	84	33	27	545
	short	19%	44%	54%	49%	29%	39%	47%	55%	48%	67%	47%
	medium	48%	39%	30%	30%	50%	31%	47%	27%	36%	22%	32%
	long	33%	17%	15%	21%	21%	30%	7%	18%	15%	11%	21%
Market participants	#	34	33	44	50	31	27	26	81	32	31	39
Market makers	#	23	23	10	7	23	25	20	10	22	21	18
Trades	#	1,385	9,108	3,957	7,249	1,591	8,179	363	36,273	5,940	757	74,802
	buy/sell-ratio	0.02	-0.02	0.02	0.04	-0.25	0.01	0.07	0.01	-0.07	0.26	0.01
	at EuroMTS	14.4%	4.0%	10.8%	5.0%	11.9%	14.3%	6.9%	6.5%	11.6%	1.6%	7.8%
	per bond	66	154	50	91	114	61	24	432	180	28	137
	per day	11	73	32	58	13	65	3	290	48	6	598
Quotes	#	2,090,861	4,252,041	5,530,593	5,364,784	1,652,881	6,856,513	547,780	9,985,519	3,165,767	1,130,452	40,577,191
	at EuroMTS	47.3%	34.3%	49.2%	37.6%	46.3%	39.0%	47.3%	48.5%	46.8%	37.9%	43.5%
	per bond	99,565	72,068	70,008	67,060	118,063	51,553	36,519	118,875	95,932	41,869	74,454
	per day	16,335	33,219	43,208	41,912	12,913	53,567	4,280	78,012	24,733	8,832	317,009
Trade price	mean	117.29	104.34	109.14	102.62	108.54	107.49	106.80	102.58	108.38	94.64	106.18
	sd	12.28	9.10	12.43	5.20	7.53	9.77	4.97	4.72	10.39	9.14	8.55
	min	93.30	34.49	96.98	25.45	94.17	23.15	96.90	83.20	95.19	67.00	23.15
	max	152.70	139.14	162.82	118.85	125.53	161.78	116.84	143.59	154.69	107.93	162.82
Trade size	mean	5.27	9.01	5.64	5.42	7.82	8.11	2.87	4.78	7.95	5.05	6.19
	sd	3.15	3.26	4.50	3.94	2.96	4.22	2.69	3.80	3.52	2.14	3.42
	min	2.00	1.00	2.00	1.00	2.50	2.50	1.00	0.50	2.00	2.50	0.50
	max	25.00	100.00	50.00	50.00	30.00	90.00	20.00	120.00	80.00	24.00	120.00
Mid-quote price	mean	117.57	106.31	115.41	94.76	109.84	106.12	107.81	104.49	113.21	96.17	107.17
	sd	12.05	19.61	17.43	28.51	7.53	22.05	4.22	7.11	13.70	8.09	14.03
	min	93.16	33.79	96.82	18.30	89.75	15.98	67.56	82.00	93.00	51.65	15.98
	max	161.22	2,615.21	163.85	31,636.38	126.55	162.54	174.28	145.89	230.22	514.69	31,636.38
Quoted spread	mean	0.35	0.39	0.17	0.87	0.18	0.37	1.39	0.23	0.15	2.89	0.70
	sd	0.49	16.81	0.35	43.67	0.69	0.84	4.36	0.54	0.86	10.34	7.90
	min	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	max	79.10	5,214.38	110.06	63,272.64	55.12	193.34	215.12	106.15	206.46	925.11	63,272.64
Effective spread	mean	0.20	0.04	0.06	0.16	0.08	0.07	0.51	0.06	0.06	0.48	0.17
	sd	0.21	0.10	0.09	0.18	0.08	0.15	0.53	0.07	0.10	0.62	0.21
	min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	max	1.71	5.54	1.02	5.04	2.00	7.58	7.10	2.69	3.53	4.96	7.58

Table B.2: Desriptive statistics (by term to maturity, weekday and time of day)

Category		Term to maturity			Weekday					Time of day		
		short	medium	long	Mon	Tue	Wed	Thu	Fri	08:15-09:59	10:00-16:00	16:01-17:30
Bonds	#	255	177	113								
Trades	#	35,140	28,671	10,991	11,968	16,414	16,043	16,724	13,653	9,092	52,314	13,396
	buy/sell-ratio	0.00	-0.02	-0.05	-0.07	0.01	0.06	0.00	0.01	-0.07	0.03	-0.06
	per bond	138	162	97	22	30	29	31	25	17	96	25
	per day	281	229	88	479	657	642	669	546	73	419	107
Quotes	#	12,375,364	17,236,189	10,965,638	7,666,234	8,210,956	8,056,868	8,422,743	8,220,390	7,148,051	26,642,605	6,786,535
	per bond	48,531	97,380	97,041	14,066	15,066	14,783	15,455	15,083	13,116	48,886	12,452
	per day	99,003	137,890	87,725	306,649	328,438	322,275	336,910	328,816	57,184	213,141	54,292
Trade price	mean	102.22	107.14	110.52	105.76	105.98	106.75	106.14	106.37	105.71	106.22	106.26
	sd	2.43	5.96	12.87	8.52	8.59	8.25	8.73	8.56	8.78	8.48	8.75
	min	94.96	78.62	23.15	34.49	42.04	25.45	23.15	25.89	42.04	23.15	34.49
	max	118.86	161.78	162.82	159.60	162.82	158.89	161.78	159.90	160.69	162.60	162.82
Trade size	mean	7.68	6.00	4.06	6.20	6.13	6.17	6.31	6.07	6.19	6.21	6.06
	sd	3.87	2.79	1.86	3.43	3.50	3.43	3.37	3.12	3.09	3.43	3.52
	min	1.00	0.50	0.50	1.00	0.50	0.50	1.00	0.50	0.50	0.50	0.50
	max	120.00	30.00	23.00	75.00	100.00	115.00	120.00	100.00	80.00	120.00	100.00
Mid-quote price	mean	103.06	107.66	109.03	107.38	107.13	107.07	107.15	107.13	107.35	107.09	107.28
	sd	3.06	8.48	19.80	13.02	12.95	12.94	16.46	13.06	12.66	14.26	13.77
	min	68.36	51.65	15.98	15.98	16.42	16.61	16.99	16.98	16.53	15.98	16.42
	max	1,386.66	2,615.21	31,636.38	1,386.66	2,818.05	254.50	31,636.38	1,731.42	1,546.71	31,636.38	2,615.21
Quoted spread	mean	0.50	0.77	0.83	0.75	0.54	0.62	0.80	0.78	1.23	0.49	0.98
	sd	2.50	4.61	9.62	3.64	2.42	2.25	14.11	4.73	4.19	6.75	7.18
	min	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	max	2,682.85	5,214.38	63,272.64	2,682.85	5,635.86	398.18	63,272.64	3,444.29	3,089.92	63,272.64	5,214.38
Effective spread	mean	0.06	0.22	0.35	0.20	0.19	0.15	0.16	0.18	0.27	0.16	0.19
	sd	0.08	0.18	0.27	0.21	0.20	0.19	0.20	0.23	0.34	0.18	0.20
	min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	max	5.04	7.10	7.58	4.96	4.22	7.58	5.04	7.10	7.10	7.58	3.75

Table B.3: Regression results (by issuer)

	Two-way model HS 1997		Three-way model HS 1997				Time-corrected model HW 2006		Interdealer model BL 2015	
Issuer	Obs.	λ	Obs.	π	α	β	α	β	α	β
AT	1,364	0.1795 ***	1,343	0.3526 ***	-0.0236	0.2044 **	0.0155	0.1707 *	0.2663 ***	-0.0854 **
		(0.0268)		(0.0129)	(0.1037)	(0.0901)	(0.1032)	(0.0931)	(0.0420)	(0.0376)
BE	9,059	0.0375 *	9,012	0.3562 ***	0.0429	-0.0039	-0.0576	0.0945	0.0374	0.0016
		(0.0218)		(0.0050)	(0.0843)	(0.0832)	(0.0704)	(0.0807)	(0.0420)	(0.0336)
DE	3,879	0.2072 ***	3,804	0.3436 ***	-0.1498	0.3363 ***	0.0113	0.1943	0.3395 ***	-0.1530 ***
		(0.0357)		(0.0076)	(0.1070)	(0.0928)	(0.1428)	(0.1195)	(0.0541)	(0.0422)
ES	7,196	0.0507 **	7,146	0.3408 ***	-0.0375	0.0845 **	0.0301	0.0246	0.0865 **	-0.0395 **
		(0.0226)		(0.0056)	(0.0304)	(0.0320)	(0.0515)	(0.0563)	(0.0309)	(0.0149)
FI	1,577	0.0585 ***	1,563	0.3443 ***	-0.0171	0.0741	0.0482	0.0173	0.0906 ***	-0.0335
		(0.0189)		(0.0120)	(0.0510)	(0.0502)	(0.0568)	(0.0563)	(0.0320)	(0.0227)
FR	8,098	0.0541 ***	8,021	0.3209 ***	-0.0233	0.0767 **	-0.0708 *	0.1300 ***	0.0962 ***	-0.0428 **
		(0.0143)		(0.0052)	(0.0352)	(0.0372)	(0.0365)	(0.0459)	(0.0288)	(0.0208)
IE	350	0.1102 **	337	0.2771 ***	-0.1687	0.2637 **	-0.1722 *	0.2836 **	0.3070 ***	-0.2121 **
		(0.0435)		(0.0239)	(0.1090)	(0.1091)	(0.0957)	(0.1188)	(0.1060)	(0.0877)
IT	36,187	0.1139 ***	36,103	0.3471 ***	-0.0471	0.1575 ***	-0.0401	0.1508 ***	0.1798 ***	-0.0694 ***
		(0.0084)		(0.0025)	(0.0291)	(0.0275)	(0.0301)	(0.0277)	(0.0149)	(0.0121)
NL	5,907	0.0534 **	5,875	0.3514 ***	-0.0774 *	0.1236 ***	-0.1215	0.1545 *	0.0984 **	-0.0523 ***
		(0.0253)		(0.0062)	(0.0419)	(0.0419)	(0.0761)	(0.0792)	(0.0359)	(0.0177)
PT	730	0.0708	703	0.2918 ***	0.1095	-0.0139	0.0621	0.0307	0.0857	0.0099
		(0.0521)		(0.0168)	(0.1012)	(0.1122)	(0.1346)	(0.1645)	(0.1165)	(0.0801)
Total	74,338	0.0771 ***	73,898	0.3441 ***	-0.0239	0.1037 ***	-0.0101	0.0904	0.1268 ***	-0.0470 ***
		(0.0161)		(0.0017)	(0.0325)	(0.0321)	(0.0490)	(0.0555)	(0.0253)	(0.0146)
Min	350	0.0375	337	0.2771	-0.1687	-0.0139	-0.1722	0.0173	0.0374	-0.2121
Max	36,187	0.2072	36,103	0.3562	0.1095	0.3363	0.0621	0.2836	0.3395	0.0099

Notes: The table reports the changes in the quote midpoint. Robust standard errors in parantheses. ***, ** and * indicate significance at the 99, 95 or 90 percent level, respectively.

Table B.3: (continued)

	Bond-market model				Bond-market model with trends					
Issuer	α		β		α		β		γ	
AT	0.1429	***	0.0406	*	0.1150	**	0.0483	**	0.0549	**
	(0.0445)		(0.0221)		(0.0436)		(0.0220)		(0.0265)	
BE	0.0274		0.0015		0.0473	**	0.0015	**	0.0735	***
	(0.0273)		(0.0212)		(0.0235)		(0.0198)		(0.0217)	
DE	0.1291	**	0.0692	***	0.1184	**	0.0652	**	0.0789	**
	(0.0568)		(0.0245)		(0.0549)		(0.0246)		(0.0355)	
ES	0.0406	**	0.0147		0.0663	**	0.0174		0.0884	***
	(0.0199)		(0.0093)		(0.0249)		(0.0104)		(0.0178)	
FI	0.0525	**	0.0122		0.0532	**	0.0097		0.0037	
	(0.0216)		(0.0129)		(0.0226)		(0.0131)		(0.0196)	
FR	0.0218		0.0210	*	0.0144		0.0239	*	0.0156	
	(0.0146)		(0.0118)		(0.0162)		(0.0126)		(0.0139)	
IE	-0.0089		0.0883	**	-0.0703		0.0793	**	0.1502	***
	(0.0410)		(0.0378)		(0.0551)		(0.0378)		(0.0530)	
IT	0.0740	***	0.0347	***	0.0613	***	0.0275	***	0.1316	***
	(0.0119)		(0.0067)		(0.0134)		(0.0067)		(0.0099)	
NL	0.0094		0.0311	**	0.0149		0.0260	**	0.0549	**
	(0.0261)		(0.0117)		(0.0257)		(0.0117)		(0.0226)	
PT	0.0944	**	-0.0085		0.0985	*	-0.0089		0.0918	*
	(0.0465)		(0.0356)		(0.0496)		(0.0323)		(0.0540)	
Total	0.0589	***	0.0208	**	0.0579	***	0.0212	**	0.0857	***
	(0.0157)		(0.0091)		(0.0178)		(0.0089)		(0.0132)	
Min	-0.0089		-0.0085		-0.0703		-0.0089		0.0037	
Max	0.1429		0.0883		0.1184		0.0793		0.1502	

Table B.4: Regression results (by term to maturity, weekday and time of day)

Category		Obs.	Bond-market model π	Bond-market model α	Bond-market model β	Bond-market model with trends α	Bond-market model with trends β	Bond-market model with trends γ
Term to maturity	short	34,684	0.3330 ***	0.0290	0.0240	0.0218	0.0233	0.0354
			(0.0025)	(0.0297)	(0.0196)	(0.0354)	(0.0211)	(0.0324)
	medium	28,385	0.3598 ***	0.0424 **	0.0108	0.0474 **	0.0162	0.0793 ***
			(0.0028)	(0.0203)	(0.0116)	(0.0226)	(0.0124)	(0.0169)
	long	10,829	0.3384 ***	0.0763 ***	0.0288 **	0.0741 **	0.0240 *	0.0978 ***
			(0.0045)	(0.0253)	(0.0142)	(0.0297)	(0.0135)	(0.0223)
Weekday	Mon	11,823	0.3419 ***	0.1091 **	0.0181	0.1104 ***	0.0138	0.1743 ***
			(0.0043)	(0.0455)	(0.0197)	(0.0371)	(0.0150)	(0.0480)
	Tue	16,328	0.3415 ***	0.0731 **	0.0432 **	0.0819 **	0.0387 **	0.0514 *
			(0.0037)	(0.0363)	(0.0171)	(0.0391)	(0.0184)	(0.0275)
	Wed	15,720	0.3360 ***	0.0965 ***	0.0068	0.1003 **	-0.0023	0.1222 ***
			(0.0038)	(0.0292)	(0.0189)	(0.0254)	(0.0185)	(0.0189)
	Thu	16,446	0.3470 ***	0.0658	0.0122	0.0379	0.0089	0.0966 ***
			(0.0037)	(0.0396)	(0.0211)	(0.0449)	(0.0211)	(0.0288)
	Fri	13,581	0.3550 ***	0.0132	0.0182	0.0055	0.0347 **	0.0555 ***
			(0.0041)	(0.0170)	(0.0143)	(0.0198)	(0.0146)	(0.0133)
Time of day	08:15-09:59	8,978	0.3543 ***	0.1113 **	-0.0048	0.1204	0.0174	0.1134 **
			(0.0050)	(0.0531)	(0.0391)	(0.0743)	(0.0413)	(0.0409)
	10:00-16:00	51,676	0.3440 ***	0.0314 **	0.0288 ***	0.0219	0.0257 ***	0.0851 ***
			(0.0021)	(0.0117)	(0.0091)	(0.0144)	(0.0086)	(0.0125)
	16:01-17:30	13,244	0.3376 ***	0.1050 **	0.0021	0.1071 **	0.0030	0.0769 **
			(0.0041)	(0.0491)	(0.0275)	(0.0497)	(0.0277)	(0.0281)

Notes: See Table B.3.

5 The influence of political communication on the price discovery process in sovereign bond markets

Abstract

This chapter aims to shed light on the signaling effects of political communication on sovereign bond trading in times of financial crisis. Our sample covers high-frequency quote and trade data of more than 500 euro-denominated sovereign bonds for the period between January 2 and June 28, 2013, when the bailout of Cyprus caused heated debates on bank deposit levies and bail-in procedures. Within the framework of a market microstructure approach, we find press conferences, speeches, interviews and written statements of political actors to have demonstrable effects on the quoting behavior of institutional investors. Communications on attempts to break the sovereign-bank nexus have a coordinating and soothing effect, while discussions on Cyprus' role as a template for future rescue measures trouble the markets. However, the impact holds for a maximum of 30 minutes and largely depends on the originator of the statement. We conclude that in times of market uncertainty, public signals can be an important source for investment decisions in sovereign bond markets. To have a lasting effect, however, a coherent communication strategy is necessary.

5.1 Introduction

"[...] Last week we didn't go down the bail-in track but went down the levy track. Now we're going down the bail-in track. [...] That is a sort of

> *shift in approach."* (Jeroen Dijsselbloem, President of the Eurogroup, on March 25, 2013)

The turmoil in the banking sector of the third smallest eurozone economy has made clear that even years after the beginning of the sovereign debt crisis, EU's crisis management is far from operational readiness. The trouble at the global financial markets was inflamed first by months of virtually no communication on Cyprus' 17 billion euro request, and boiled over in March 2013 when EU and national officials issued heterogeneous and partly conflicting statements on the novelty of bank deposit levies and Cyprus' role as a template for future rescue packages in the eurozone. Against this background, the goal of this chapter's research is to deepen our understanding of the relevance of political communication on financial markets in times of economic distress.

Due to an accommodating global environment and promotion of policy measures like double-tax agreements, a low corporate tax rate and favorable bank interest rates the Cypriot banking system was largely oversized. In 2010, the size of the banking sector exceeded nine times national GDP (Stephanou, 2011). It was dominated by two domestically-owned institutions, the Bank of Cyprus and the Laiki Bank, which had large offshore activities. According to the IMF (2011), the exposure of Cypriot banks in Greece was about EUR 29 billion or 160 percent of national GDP. The Greek haircut in early 2012 led Cypriot banks to write-down liabilities between EUR 4.5 and 5 billion. As a consequence of the European bank stress test, capital requirements were raised. Rising unemployment and weak economic growth between 2010 and 2012 led to a significant share of non-performing loans which further increased the pressure on domestic banks. Through expansionary policies, the government gambled away the confidence of international investors and lost access to capital markets in May 2011. The downgrading of all three major rating agencies made sovereign debt not eligible as collateral for borrowing from the Eurosystem anymore. All of these developments caused the Cypriot government to formally ask for an emergency loan during summer 2012.

The following months were marked by virtually no communication on Cyprus' request for financial assistance. If anything, national and European officials repeatedly reassured that bank deposits would be safe. On March 16, 2013 the troika of creditors[27] announced a EUR 10 billion emergency loan. They also brought into effect a levy of 6.7 and 9.9 percent respectably on bank deposits below and above EUR 100,000. Uncertainty and speculation grew, since no official communication elucidated details of this novel procedure. Three days later, the Cypriot parliament voted against the proposed tax on bank accounts, but both citizens and financial markets again obtained no information about any alternative plan. Meanwhile, the Cypriot finance minister failed to arrange a five-year extension of an existing loan from Russia.[28] Finally, on March 25, the alternative plan was announced. It consisted of a resolution of the Laiki Bank, a restructuring of the Bank of Cyprus, the alienation of all offshore activities in Greece, and a levy of 47.5 percent on uninsured deposits above EUR 100,000. This was the first time in history of the European debt crisis that bondholders, shareholders and large depositors had to pay (part of) the bill. Meanwhile, communication concentrated on empty phrases of courage and hard work. In the aftermath, both economists and press voiced doubts and termed the ad-hoc "bail-in" procedure unfair, short-sighted and self-defeating. What was ultimately learned from the Cypriot financial crisis of 2012-13 is an unstructured and non-coordinated communication of European policymakers.[29]

In the further course of this chapter, we define political communication as a strategic use of communication by political actors with a particular emphasis on the purpose and intentionality of them in affecting their environment (Denton and Woodward, 1990, McNair, 2011). This includes oral and written political rhetoric, like press conferences, speeches and interviews. Against this background, we analyze the real-time impact of hundreds of Cyprus-related statements on Europe's fixed income markets. Sovereign bond trading is typically organized in quote-driven dealer markets. Selected market participants are obligated to offer instant trading opportunities by posting executable bid and offer prices. The difference between these two prices

[27] A group formed by the European Commission, the European Central Bank and the International Monetary Fund that negotiated on credit programs with eurozone member states.

[28] About 50 percent of deposits in the Bank of Cyprus belonged to non-EU residents, and much of the funds were suspected to belong to Russian investors.

[29] Potential negative effects of careless communication by policymakers during times of high financial market uncertainty were spotlighted by The Economist (2011) already in 2011.

is the bid-ask spread, which represents a compensation for making the market.[30] Thus, market liquidity hinges in large part on the capacity and willingness of a few market participants. Most often investment banks operate as dealers. We expect communication on the debt and banking crisis may have demonstrable effects on the quoting behavior of these institutional investors for two reasons. First, discussions on a first-time break of the sovereign-bank nexus might lead to revaluations of European sovereign bonds in a bank's asset portfolio.[31] The costs of rescuing a systemically relevant bank get internalized and no longer burden the national budgets of other eurozone member states. Second, if the bail-in of shareholders, bondholders and depositors represents a template for rescuing struggling banks within the eurozone, other financial institutions might decide to adjust their bond market quotations for hedging reasons. Potential interventions on the liabilities side of a bank's balance sheet could make it necessary to actively adjust the assets side.

This chapter's research relates to several, sometimes overlapping, strands of literature. The first strand focuses on central banks and the role of communication as a policy tool. The importance of communication between central banks and financial markets for reasons of monetary policy efficacy and, more recently, of financial stability started to be acknowledged in the early 1990s. Today, leading central banks worldwide are aware of the importance of verbal discipline in anchoring market expectations. If nothing else, it was the speech by Mario Draghi in July 2012 stating that the ECB will do "whatever it takes to preserve the euro" that is commonly known as an important turning point in the European sovereign debt crisis.[32] The effects of ECB communication during the recent crisis have been studied by Conrad and Lamla (2010), Falagiarda and Reitz (2013), and Amaya and Filbien (2015), among others. They find announcements to be significant in affecting equity, foreign exchange and bond market returns and volatility. Dewachter et al. (2014) analyze intra-day effects of statements on the euro-dollar exchange rate and find

[30]For a detailed discussion see Chapter 3.

[31]As of January 2017, government debt securities accounted, on average, for about 12 percent of combined assets of eurozone's financial institutions, while sovereign bond holdings were the largest in the southern periphery (European Central Bank, 2017a).

[32]Valuable reviews on both theoretical and empirical literature are provided by Blinder et al. (2008), Eijffinger and van der Cruijsen (2007) and Blattner et al. (2008).

that communication triggers large jumps for approximately an hour. The literature further finds that the impact on financial markets is larger the more formal the communication is and the more prominent the position of the speaker is (e.g. Kohn et al., 2003, Ehrmann and Fratzscher, 2007).[33] However, one must bear in mind the fundamental differences between central banks and politicians. First, the former are important players in financial markets. They communicate mostly about well-known and commonly accepted targets and instruments (Woodford, 2005). Furthermore, they may have already built up a sound reputation on which confidence is based. Both of these arguments in favor of central bank communication do not, or at best, only slightly apply to political communication.

A second strand of literature our work builds upon concentrates on the impact of macroeconomic news on financial markets. Fleming and Remolona (1999) study sovereign bond market reactions after monthly U.S. statistic data releases like the unemployment rate, GDP, PPI, CPI, retail sales and trade balance. They find that most of these announcements significantly impact treasury yields over the complete yield curve. On the basis of real-time exchange rate quotations, Andersen et al. (2003) investigate the way news on fundamentals are incorporated into foreign exchange markets. They find that adjustments of exchange rates to news occur quickly, are greater for bad news than for good news, depend on its timing and whether the announcement time is known in advance or not. Andersen et al. (2007) extend the analysis to stock and bond markets and show that the latter react most strongly to macroeconomic news. However, a core difference between macroeconomic news and political communication is that the former are, in most cases, scheduled and recurrent, which makes explicit market reactions more likely. Closer in spirit to our research is the work of Beetsma et al. (2013) who analyze the European sovereign bond market between July 2007 and February 2012. They make use of the daily newsflash of Eurointelligence, which provides reports on economic and financial news and political events in Europe. Their core findings are that more news about a crisis country drives up the country's yield spread compared to Germany; they observe spill-overs

[33] However, there is a also large debate on the limits of transparency (Morris and Shin, 2002, Svensson, 2006, Cukierman, 2009).

of news concerning one crisis country onto other crisis countries and investigate that bad news has a larger impact on spreads than good news. Concerning the role of European institutions, Goldbach and Fahrholz (2011) show that the European Commission played an important role in affecting investors' evaluations. However, Smeets and Zimmermann (2013) investigate that crisis meetings of the European Council and subsequent press conferences have, at best, a short impact on European financial markets.

The final strand of literature, which is closest to our research question, focuses on the impact of political statements on financial markets. In the context of the European debt crisis, Mohl and Sondermann (2013), Gade et al. (2013) and Büchel (2013) monitor the impact of announcements and speeches (about restructuring, bailout, involvement of euro rescue funds, among others) on bond yield and CDS spreads by means of daily data for the period between 2009 and 2011. One of the core results is that in times of uncertainty political communication may have immediate and quantifiable effects on sovereign bond and CDS spreads. They further show that spreads increase more strongly the more policymakers talk at the same time. Finally, they find that financial market reactions are larger when policymakers come from Germany, France, or an EU institution than when the communication originated from a small eurozone country. By exploring reasons for these phenomena, Gade et al. (2013) find that the specific economic, political and institutional setting of the eurozone increases the potential for miscommunication.

So far, the academic literature has concentrated largely on the development of financial market aggregates on a daily basis. We go one step further and analyze on a micro-level the real-time impact of hundreds of statements of national and international political actors on the trading behavior of institutional investors. For our analysis we use six months of high-frequency quote and trade data from one of the most important interdealer platforms for trading European sovereign bonds, MTS Cash. The communication data is extracted from Reuters' newswire service. Using intraday data allows us to monitor the effects in real time and to avoid problems with respect to identification and causality. For a profound analysis, we embed political communication into a market microstructure framework. This literature attempts to find theoretically sound explanatory approaches for investor behavior. Our model framework follows the seminal work of Huang and Stoll (1997) to decompose the price reaction into investment-specific motives. Correcting for sovereign bond market specific factors, like block trading, hedging and interdealer trading, we try to find out the impact of communication on the distribution of information in the market and the price risk of inventory holding. We ask: Did the renewed flare-up of the sovereign debt crisis and the communication about it lead to any change in investment behavior in bond trading? What determines the investment decision to buy or sell a specified amount of an asset? Is communication by political actors a relevant public signal that may influence investment behavior, at least in times of crisis?

The chapter's findings suggest that political communication about the Cypriot debt and banking crisis had important repercussions for sovereign bond prices. In the course of an event study approach, we find press conferences, speeches, interviews and written statements of political actors to have demonstrable effects on the short-term quoting behavior of dealers in the secondary bond market. In many cases, bid and ask price quotations converge for up to half an hour, which speaks in favor of a coordination effect of public signals. Effects are largest for Italian sovereign bonds, but are also observable for Austrian, Belgian, German, Spanish, Finnish, French and Dutch securities. However, the impact of political communication largely depends on the content. While statements that are dedicated to breaking the sovereign-bank nexus, either in the form of a levy on bank deposits or a bail-in of shareholders and bondholders of a bank, have a strong coordinative effect, discussions on systemic relevance of Cyprus and its function as a template for future bailouts trouble the markets. Concerning the originator of the statement, the coordination effect is large for those policymakers who play an active role in bailout negotiations and who enjoy a sound reputation. This holds true especially for the heads of the troika institutions, namely Draghi, Lagarde and Barroso, but also for the German finance minister Schaeuble and Cypriot politicians. In contrast, statements by the new head of the Eurogroup, Dijsselbloem, lead to an expansion of bid-ask spreads and thus to a deterioration of liquidity conditions for up to one hour. Changing to a microstructure perspective and taking executed trades into account, we are able to show that after half an hour the informational role of trading increases, i.e. the level of information asymmetry in the market and the price risk of inventory holding increase. This is the case especially for trading Belgian, French and Italian debt securities. The same holds true for statements emphasizing the systemic relevance of Cyprus, the discussion on bank deposit levies as well as the bail-in procedure. The effects are also observable for politicians with high public perception. We conclude, that especially in times of crisis, political actors should consider communication as an important component of their policy toolkit. To have lasting effects on financial markets, a coherent communication strategy is highly recommended. This is particularly true in a complex multilingual and multicultural entity like the European Monetary Union.

The remainder of this chapter is structured as follows: Section 5.2 delivers explanations of why, and through which channels political communication may have an effect on financial markets. Section 5.3 develops a structural model for sovereign bond trading and presents the ways we incorporate political communication into a microstructure framework. Section 5.4 provides an overview of the high frequency trading and communication data we use, while Section 5.5 presents the estimation procedure. Section 5.6 outlines the main empirical results. Finally, Section 5.7 summarizes the findings and discusses important policy implications.

5.2 Why communication matters

There are several reasons why we expect political communication to be an important signaling device for financial market participants in times of crisis.

First, eurozone's strategy to manage the crisis resulted from a makeshift decision-making process. Even if the global financial crisis led to severe troubles of some dozens of European banks and national budgets, up until March 2013 the eurozone member states were neither able to break the sovereign-bank nexus, nor to pass legislation concerning a sovereign default procedure within the monetary union. Instead, tough bargaining took place in Brussels back-rooms and wide-ranging decisions were made by a small group of policymakers. Subsequent interviews, press conferences, and written statements marked the first time that private information on bailout packages and bail-in procedures became public knowledge. At that time, political communication was virtually the only reference for financial market participants to anticipate planned interventions.

Second, the handling of the crisis came along with a constant learning process not only by policymakers, but also about them. However, three of the most relevant political offices changed during the crucial phase of negotiations. Just before the end of the bailout negotiations Jeroen Dijsselbloem followed Jean-Claude Juncker as head of the Eurogroup[34], Nicos Anastasiades became the newly elected president of Cyprus and Michael Sarris the new finance minister in charge of the bailout negotations. This made it even more difficult to anticipate political actions, and political communication was one of the few sources available to gain insight into the political actors.

Matters are complicated further by the eurozone's institutional features. Besides the discrepancy of monetary and fiscal integration, the euro area is a complex political system with a difficult allocation of competences. The crisis of Cyprus has shown that representatives of 18 national governments, supranational institutions and international entities took an active part in bailout negotiations. All these participants gave interviews or published written statements on the same issue but with their own national and international interests in mind. This goes along with the problem that statements on the same issue are often assigned for different audiences. This chorus of (partly conflicting) voices might have further influenced market expectations.

Having argued that communication may matter, the question arises of what effects political statements could have on financial markets. Especially in times of market uncertainty, contentful and confidence-inspiring statements may work as a coordination device which reduces heterogeneity in market expectations. This may induce price quotations to more closely reflect the fundamental value of an asset causing market liquidity to rise. Of course, it is also possible that public signals sow confusion among traders. They may struggle for some time to settle on an updated

[34] The Eurogroup is an informal group of the finance ministers of the eurozone. This group was in charge of working out the bailout plan. Dijsselbloem became the head of this group in January 2013.

opinion of the fundamental value of an asset. Communication may further increase information asymmetry if investors differ in their ability to interpret the signal or if they pay attention to it at different times. By this point, it is not clear whether political communication increases concern or restores homogeneity in expectations.

The Cypriot crisis makes it reasonable to assume that country specific communication not only provides information on the respective country, but also affects other countries facing comparable challenges. The bailout of the fifth eurozone member state delivers an indication for the troika's general commitment to support indebted countries. The public discussion on bank deposit levies and Cyprus' role as a template for future rescue measures reveal European policymakers' opinion on a participation of shareholders, bondholders and depositors. These are the reasons we expect that policy signals for a specific country also serve as a landmark in the assessment of other troubled member states of the eurozone.

5.3 Model framework

Before we scrutinize the motives behind investment decisions, we follow a rough intuition and solely resort to quote data from the limit order book. Due to the high-frequency data structure, this may give us a good indication of whether there is an impact of political communication on the quoting behavior of dealers in general. Formally,

$$\Delta S_t^{quoted} = \sum_{c=1}^{C} \gamma_c COM_{ct-1} + \epsilon_t, \tag{5.1}$$

where ΔS_t^{quoted} represents the change in the quoted spread that occurs immediately after the "communication event" of type c, COM_{ct-1}. This allows us to answer the question of whether communication has an immediate effect on liquidity conditions in the market.

After identifying the general impact of statements on the limit order book, we go one step further and make use of the two-way decomposition model of Huang and Stoll (1997). The widely applied trade-indicator model attributes changes in dealer quotations to unanticipated public information shocks and trade-specific effects.

The short-run evolution of prices is formalized in Equation 5.2. The change in the quote midpoint is given as

$$\Delta M_t = \lambda \frac{S_{t-1}}{2} Q_{t-1} + \epsilon_t. \tag{5.2}$$

S_{t-1} is the effective bid-ask spread, which is calculated as twice the absolute difference between the trading price at $t-1$ and the quote midpoint valid up to a millisecond before the trade. Q_{t-1} is a trade direction indicator which equals $+1$ for a market buy order and -1 for a sell order at $t-1$. λ represents the fraction of the half-spread by which the quote midpoint responds to the previous trade. ϵ reflects the deviation from this relationship. Since the model assumes rationality, i.e. all price-relevant information is priced in immediately, ϵ can be interpreted as a serially uncorrelated public information shock. Thus, the quote midpoint changes either because of the arrival of unanticipated public information or because the last trade conveys relevant information on the behavior of other traders in the market.

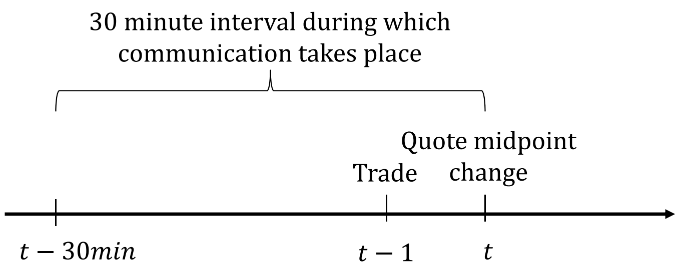


Figure 5.1: Timeline

We examine how political communication influences the quoting behavior of dealers through several modifications to Equation 5.2. In a first step, we include a set of dummy variables that take a value of 1 if the "communication event" happens within a thirty minute period before the change of the bid and ask price quotations and 0 otherwise.[35] This allows us to capture the direct effect of political communication on prices. The schedule is illustrated in Figure 5.1. Formally, this results in

[35]Sovereign bond trading is characterized by frequent quote adjustments but seldom executed trades. To analyze the impact of both political communication and transactions on dealers' quoting behavior, a relatively large interval is necessary. We discuss this in more detail in the further course of this chapter.

$$\Delta M_t = \lambda \frac{S_{t-1}}{2} Q_{t-1} + \sum_{c=1}^{C} \gamma_c COM_{ct-1} + \eta_t, \tag{5.3}$$

where COM_{ct-1} is the "communication event" of type c that occurs within a thirty minute interval before the quote midpoint change. γ_c measures the sensitivity of dealers to political communication of type c, respectively.

Until now, we are only able to distinguish between an unspecified order flow effect and a public information effect. To shed some light on the microeconomic motives behind price-setting decisions, we make use of the three-way decomposition model of Huang and Stoll (1997). The model isolates different spread components by examining the relationship between quote changes and the direction of the previous trade. This enables us to analyze changes in the microstructure parameters around political communication events. Formally, the change in the quote midpoint is given as

$$\Delta M_t = (\alpha + \beta) \frac{S_{t-1}}{2} Q_{t-1} - \alpha(1 - 2\pi) \frac{S_{t-2}}{2} Q_{t-2} + \epsilon_t. \tag{5.4}$$

λ is now divided into α, which represents the information asymmetry component, and β, which captures the impact of inventory holding costs.[36] The fundamental concept to measure both components simultaneously is represented by the second term on the right-hand side, which subtracts the private information in Q_{t-1} that is not a surprise. The trade reversal indicator, π, is the time-independent probability that the trade at $t-1$ is opposite in sign to the trade at $t-2$.[37] Only a deviation from expected order flow, i.e. that a purchase is followed by another purchase even if the expected order flow would suggest a sale, comprises price-relevant private information. When $\pi = 0.5$, the trade at time $t-1$ contains no predictable information and a separation of information asymmetry and inventory holding factors is not possible. Since the model of Huang and Stoll (1997) decomposes the change in the quote midpoint into

[36] A detailed discussion on the derivation of Equation 5.4 is provided in Chapter 4.

[37] The conditional expectation of the trade indicator in $t-1$, given Q_{t-2} is known, can be rewritten as

$$E(Q_{t-1}|Q_{t-2}) = (1-\pi)Q_{t-2} + \pi(-Q_{t-2}) = (1-2\pi)Q_{t-2}. \tag{5.5}$$

relative cost shares, it is common to interpret $(1 - \alpha - \beta)$ as the weight of order processing costs.

The decomposition model of Huang and Stoll (1997) is widely used, since it is among the few models that allow to separate all three cost components. However, even in single dealer equity markets like the NYSE, for which the model is designed, the empirical performance is not always satisfactory. As discussed in detail in Chapter 4, we refine the model with respect to fixed-income trading. The modified model captures a set of relevant market features and largely improves the empirical performance of spread decomposition models in sovereign bond trading. The final bond market model is

$$\Delta M_t = (\alpha + \beta)\frac{S_{t-1}}{2}Q_{t-1} - \alpha(1 - 2\pi)\frac{S_{t-1}}{2}Q_{t-2} - \beta\frac{S_{t-2}}{2}Q_{t-2} + \epsilon_t. \tag{5.6}$$

The second term on the right-hand side differs by the timing of the spread that should be determined by the timing of the unexpected part of the order flow in $t-1$. In addition, there is a third term that corrects for the possibility of active trading with other dealers in the market, which reduces the importance of unwanted inventory positions.[38]

To capture the effects of political communication on information asymmetry, inventory holding and order processing, we include a set of dichotomous variables. Formally,

$$\Delta M_t = (\alpha+\beta)\frac{S_{t-1}}{2}Q_{t-1}\sum_{c=1}^{C}\gamma_c COM_{ct-1} - \alpha(1-2\pi)\frac{S_{t-1}}{2}Q_{t-2} - \beta\frac{S_{t-2}}{2}Q_{t-2} + \epsilon_t, \tag{5.7}$$

where COM_{ct-1} is the "communication event" of type c that occurs within a thirty minute interval before the quote midpoint change. This allows us to analyze whether political communication has any effect on the distribution of information between traders, on a dealer's valuation of inventory holding costs and on order processing costs.

[38]For a detailed discussion on all modifications see Chapter 4.

5.4 Data and market structure

This section introduces the underlying data set. After a short description of the available raw data, we explain our cleaning procedure as well as some stylized facts on the event study sample and the microstructure sample. Subsequently, we describe the process of identifying the relevant communication.

5.4.1 Bond market data

The financial data set used in this study stem from MTS Cash, which represents the largest electronic interdealer platform for trading European sovereign bonds.[39] The data set covers 125 trading days from January 2 to June 28, 2013. Each trading day starts at 8:15am and finishes at 5:30pm (CET/CEST). It provides us with details on 62,609,067 quote revisions and 183,587 transactions, which are recorded with millisecond time stamps. For each transaction we have information on price, quantity and whether it is seller-initiated or buyer-initiated. The limit order book entries deliver information on the three best bid and offer prices as well as the associated quantities. The cleaning procedure takes the two-tier structure of MTS Cash, block trading and bond-specific selection criteria into account and is discussed in detail in Chapter 4.3.1.

The first part of our analysis concentrates on the impact of political communication on the quoted bid-ask spread. Therefore, we concentrate solely on the limit order book. The analysis is confined to regular bid and ask price quotations of euro-denominated fixed-rate coupon and zero coupon bonds issued by the national treasuries of 11 European countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, Slovenia and Spain. Since the accuracy of our communication data is “only” exact to the minute, we aggregate the data to 111 five-minute intervals per bond per day. Ederington and Lee (1993) and Fleming and Remolona (1999) show that most of the price response to scheduled macroeconomic announcements is completed within one or two minutes. A further reduction of the interval length, however, would result in too many intervals with no quotations. In line with Mazza

[39]For more information on MTS see Chapter 2.6.

(2015) we argue that the interval length of five minutes allows to detect quote changes around political communication and avoidance of market microstructure noise from intervals in which no quote revisions took place.[40] We include all sovereign bonds, for which the number of quote revisions in the limit order book exceeds five "improving" quotes per interval, demonstrable in at least 11,100 of 13,875 intervals between January and June. Thus, we concentrate on the most liquid sovereign bonds in the market. The cleaned dataset is reduced to 4,536,775 entries consisting of information on the high-low-mean-median quotes per interval of 346 sovereign bonds.

For our microstructure approach, we take quote and trade data into account. Again, we concentrate on euro-denominated fixed-rate coupon and zero coupon sovereign bonds issued by national treasuries. Since the number of transactions of Slovenian bonds is fairly low in our sample, we exclude the Slovenian market from the microstructure analysis. The final dataset is confined to 74,802 transactions and subsequent quote revisions of 545 sovereign bonds. Stylized facts of the data set are extensively discussed in Chapter 4.3.1.

5.4.2 Data on communication

To evaluate the impact of political communication on the quoting behavior of dealers, we make use of Reuters' real-time newswire service, which is one of the most commonly used sources of public information. For the period from January 2, 2013 to June 28, 2013, we apply a search algorithm scanning the reports for a predefined set of words, namely "Cyprus" and the last name of selected European policymakers. We include the names of all heads of state or government and finance ministers of the 17 member states of the eurozone, since they played a decisive role in the decision-making process on Cyprus. For the sake of completeness we add the names of the respective ministers of economic affairs and—if available—the ministers of European affairs. We further include a number of EU officials, namely Barroso (President of the Commission), Rehn (Commissioner of Economic and Monetary Affairs), Van Rompuy (President of the Council), Juncker and Dijsselbloem (Heads of the Eurogroup), Schulz (President of the Parliament), Draghi (President of the ECB)

[40] In our further analysis we evaluate the sensitivity of the results to a change in the interval length.

and further ECB Executive Board members as well as national governors. Since the International Monetary Fund (IMF) is part of the troika of creditors, we further include the IMF Managing Director, Lagarde.[41] The extracted data set contains more than 5,000 reports with direct and indirect quotations of interviews, speeches and official statements from 93 policymakers.

Since one statement is often followed by several reports, we adjust the data set by including only the first report and eliminating all replications. This cleaning procedure results in 330 newswire reports which we expect to contain a relevant public signal for the buying and selling decision of European bond market participants.

We scan these reports for different semantic features to better account for the content and intention of communication. We distinguish between statements that are in favor of a bailout of Cyprus and statements that convey concerns about the rescue of a further country of the eurozone. As is shown in Figure C.1, the question of whether Cyprus is of systemic relevance for the eurozone or not was publicly discussed around European Council and Ecofin meetings in January and February 2013. The German finance minister Schaeuble, but also the managing director of the European Stability Mechanism (ESM) Regling, pointed out that a threat to the entire eurozone is a necessary prerequisite for ESM assistance. At this time, Schaeuble made clear that he was skeptical towards the systemic importance of Cyprus. Draghi and other members of the ECB Executive Board emphasized the linkages between the Cypriot banking sector and those of Greece and other eurozone member states. They argued that a default could have strong domino effects within the eurozone. As early as March 2013, the public debate changed to the future of Cyprus' "business model". Many of the other member states of the eurozone expressed that they were no longer willing to foot the bill. While nobody was delighted by a levy on bank deposits below EUR 100,000, almost all decision-makers emphasized the necessity of breaking the sovereign-bank nexus. During the following days, the Cypriot parliament rejected the rescue plan. Those who argued before that there are no alternatives to a bank deposit levy emphasized now the unfairness of such a measure. Voices were raised that a bail-in of shareholders and bondholders would be the right way to share the

[41] The complete list of policymakers is provided in the Appendix (see C.1).

burden. The final rescue plan was announced on March 25, 2013. Dijsselbloem declared the deal as a success and a blueprint for potential future bailouts in the eurozone. Dozens voiced concerns and emphasized that Cyprus is a specific case. As is shown in Figure C.1, the discussion on Cyprus' role as a template continued until May 2013. Table C.2 summarizes the results of our classification.

Our approach requires some caveats. First, a newswire service may be selective and thus not all relevant statements may be reported. However, the aim of this chapter's research is to analyze the price reaction to those statements that become publicly available. This is quite likely with our approach, since Reuters is the leading international news agency. Another caveat is that Reuters may misinterpret a statement and thus the report does not reflect the true intention of a policymaker. To reduce the problem, we focus only on the first report of a statement which should be due to its timely nature without too much analysis and interpretation (Born et al., 2014). Experience has shown that most often the first reports are posted within minutes after a policymaker's statement and consist of only the quotation and two or three descriptive sentences, while later reports are longer with additional paragraphs containing background information. We could also argue that the interpretation is provided by professionals who should know about the fine nuances and subtle changes in political communication (Fratzscher, 2006). Finally, our approach is vulnerable to misclassification. To overcome this, two people classified independently of each other the statements into the categories described above. Of course, this approach is subjective and requires some level of educated judgment but in contrast to mechanical software classification we are able to consider the context of each statement. Only those reports that are exactly classifiable remain in our data set.[42]

The precise time stamp (EST/EDT) of each report allows us to allocate the statements to the appropriate trades and quotes. Statements during weekends or in the evening were allocated to the beginning of the subsequent trading day. The final selection allows a breakdown according to speaker, topic and across time. Descriptive statistics are summarized in Table C.2 and Figure C.1.

[42] A comprehensive discussion of various forms of content analysis in the context of central bank communication is provided by Blinder et al. (2008).

5.5 Estimation procedure

5.5.1 Event-study approach

Before going into the microstructure analysis, we follow a rough intuition and resort to the event study approach. Event studies represent a widely used (and controversially discussed) method in financial econometrics to estimate the wealth and price effects of a given type of event. If we assume that financial market participants act rational and process publicly available information in an efficient and unbiased manner, the basic idea is to link "abnormal" quotation activities to the events of interest by comparing the pattern of financial market movements around each event.[43] Due to the high frequency of our data, we should overcome, at least to some extent, the typical causality problem of event studies.

The question we want to address is whether political communication has an immediate and direct effect on the quoting behavior of dealers in the secondary market for trading sovereign bonds. If communication reveals new and unexpected information, an immediate price reaction should be observable. We therefore define the release of a speech or an interview as an event. Due to the exact time stamp, we are able to assign the event to the corresponding five-minute interval of our limit order book data. The narrow event window supports the assumption that communication is contemporaneously exogenous, i.e. $E(\epsilon_t|X_t) = 0$, which is needed to establish consistency of the coefficients' estimates.

A crucial issue in any event study is to find a benchmark model to calculate regular price movements, which in turn allows the calculation of abnormal price changes attributable to the events of interest. We decided to use a simple mean return model. For sovereign bond i and event interval t we calculate the abnormal spread change in the following way:

$$\Delta AS_{it} = \Delta S_{it} - \frac{1}{T_{int,d,m}} \sum_{t=1}^{T_{int,d,m}} \Delta S_{it}, \tag{5.8}$$

[43] The efficient-market hypothesis was developed by Fama (1970). We assume the semi-strong form of the hypothesis, i.e. prices reflect all publicly available information and instantly change to reflect new public information.

where S_{it} is the actual change of the quoted spread of bond i during interval t and the second term on the right-hand side represents the average change of the quoted spread of bond i over all changes during the same day interval, the same weekday and the same month in our sample.[44] This should absorb regular intraday, weekday and seasonal effects and thus the typical time-varying volatility in high-frequency data.[45] To put it simply, we adjust changes of the quoted spread for the regular time-dependent liquidity conditions in the market. This can lead to an increased ability to detect (real) communication effects.

We use this approach not only to analyze the contemporaneous effect of political communication, but also to find out potential anticipation and persistence effects. We therefore analyze pre- and post-event periods of 5, 10, 15, 30, 60 and 90 minutes. This provides us with the opportunity to consider sovereign bond market behavior over various time horizons. However, one has to bear in mind, that the longer the window length, the larger the risk of having other (non Cyprus-related) news arriving and influencing the results.

5.5.2 Microstructure approach

For the analysis of dealers' motives behind quote revisions, we change into a microstructure perspective. This allows us to answer the question through which channels communication might influence the investment behavior of primary dealers.

As discussed in Chapter 4, we use the GMM procedure to estimate the two-equation system. This ensures a common estimation framework to the literature and the previous chapter, which enhances the comparability of the results. The method is often used because of its very weak distributional assumptions. The procedure easily accommodates conditional heteroskedasticity of an unknown form and serial correlation in the residuals.

The baseline model (Equations 5.5 and 5.4) is implemented in the GMM structure by the vector function:

[44] As a robustness check, we slightly varied the composition of the second term. Core results remain stable.

[45] More details on this issue are provided in the last paragraph of Chapter 4.2.2.

$$f(x_t, \omega) = \begin{bmatrix} u_t Q_{t-2} \\ \epsilon_t S_{t-1} Q_{t-1} \\ \epsilon_t S_{t-2} Q_{t-2} \end{bmatrix}, \tag{5.9}$$

where $u_t = Q_{t-1} - (1 - 2\pi)Q_{t-2}$ and $\omega = \begin{bmatrix} \pi \alpha \beta \end{bmatrix}'$ is the vector of parameters of interest. The basic model implies the moment conditions $E[f(x_t, \omega)] = 0$. All other model specifications are implemented in the same manner. With three parameters (π, α, β) to be estimated, the models are exactly identified.

5.6 Empirical results

5.6.1 Short-term effects on the limit order book

Tables C.3 to C.6 present the estimated effects of political communication on abnormal changes of the bid-ask spread. The results give us an indication of whether there is a direct effect of communication on the quoting behavior of dealers and thus on the liquidity conditions in the market.

The last row of Table C.3 shows the estimation results of Equation 5.1 when we take the whole sample of 346 sovereign bonds and 192 communication intervals into account. Obviously, there is no anticipation effect five minutes before the announcement.[46] In contrast to frequently observable price reactions before macroeconomic news announcements or central bank communication this is easily comprehensible. Most of our communication events are unscheduled and their content is difficult to predict. Tough bargaining and wide-ranging decisions on Cyprus took place behind closed door. Quite interesting is that there is no immediate market-wide effect during the event interval. Under the assumption of rational market behavior, all new and unexpected information should be priced in immediately. One reason could be that dealers may struggle for some time to settle on an updated opinion of the fundamental value of the asset. Another reason could be our timing procedure. The data set consists of aggregated statistics over fixed five-minute intervals. When reports are

[46] The absence of anticipation effects is also observable for longer periods before the event. For reasons of clarity Table C.3 reports only the regression results of the five-minute pre-event window.

published in the last minute of an interval, it is more likely that the full price reaction is disclosed in the next five-minute interval. The regression results for the post-event period seem to confirm this argumentation. Within the five minutes after the announcement, the abnormal bid-ask spread reduces by 13.4 percentage points, on average. Thus, not distinguishing between who is speaking and what is spoken, we are able to detect a market-wide coordination effect of political communication in the interdealer market for trading European sovereign bonds. The effect decreases during the following 15 minutes but remains statistically significant at conventional levels. After 30 minutes the event-related change of the bid-ask spread becomes zero.

When we concentrate on the regression results of the country samples in Table C.3, we are able to observe that this short-term effect is largely driven by the market for Italian bonds, where the spread reduction is about 58.4 percentage points, on average. This is quite interesting, since the Italian sovereign bond market is one of the most liquid markets in our sample. However, the Italian public debt burden is large and some domestic banks hold a disproportionate share of government debt, which makes spillover effects of discussions on bailouts, bank deposit levies and bail-in procedures likely. Small coordination effects are also observable in the quotations of Austrian, Belgian, German, Spanish, Finnish, French and Dutch sovereign bonds. However, most of these price reactions happen within the first 15 minutes and last for a maximum of 30 minutes. Some country markets even show corrective developments later on. Changes in the bid-ask spread become positive and market liquidity diminishes. This supports the literature findings of only short-lasting effects of political communication.

Concerning the effects of political communication on bonds with different maturity, Table C.4 shows quite similar price setting trends. Five minutes after the announcement the bid-ask spread reduces significantly. The effect is largest for sovereign bonds with a term-to-maturity below three years. The longer the residual time to maturity, the smaller the spread reaction. An explanation for this effect is the larger share of buy-and-hold investors in the market for long-term bonds. These investors hold assets until maturity and trading as a reaction to small price changes is rather rare. Again, over time the coordination effect of political communication remains significant but diminishes. After half an hour, abnormal price reactions are not observable anymore. For medium-term bonds, bid and ask price quotations disperse during the five minutes surrounding the communication event. Even if the price reaction reverses during the following minutes, we are not able to clearly explain this development.

Table C.5 presents the limit order book reactions with respect to the statements' content. The discussion on whether Cyprus is systemically relevant for the eurozone or not, largely influences the short-term quoting behavior of institutional investors. After statements that emphasize the necessity of a bailout, the bid-ask spread increases by about 26 percentage points, on average. Even if Cyprus' request for financial assistance was comparatively small, bailing out the fifth country within four years seems to be an alarming signal to the markets. Passing the full bailout costs onto the national budgets of the eurozone partners makes their sovereign bonds less attractive. The effect remains significant for up to 10 minutes. Contrary statements, which question the importance of Cyprus and evaluate the country's problems as non-contagious, show only small coordination effects that lasts no longer than five minutes. In the further course of the crisis, discussions on bank deposit levies took place. Quite interesting is the strong coordination effect of statements in favor of a levy. The reason might be that for the first time in the history of the European sovereign debt crisis, politicians show their willingness to break the sovereign-bank nexus. Concerning dealers' asset portfolios, sovereign bonds seem to be considered as more attractive. The effect remains significant for up to 30 minutes. The market shows no significant price reaction directly after statements that exclude the involvement of deposits below EUR 100,000, even if a slight coordination effect is observable later on. One has to bear in mind that most of these statements emerged after the rejection of the troika proposal by the Cypriot parliament (see Figure C.1). This was the time when a heated debate on bail-in procedures and Cyprus' role as a template started. When political actors elucidate details of the final rescue plan, the bid-ask spreads show no clear pattern. After a short widening, the spreads show corrective developments and become smaller. However, the coordination effect then holds for up to 30 minutes. Statements that emphasize the bail-in procedure as a blueprint for future bailouts in the eurozone, lead to a significant increase of the event-related bid-ask spread by about 14 percent. In contrast, statements emphasizing that Cyprus is a specific case have a coordination effect on the quoting behavior of sovereign bond dealers.

Table C.6 presents the estimation results subdivided by speaker. The reporting concentrates on those policymakers that played an active role in bailout negotiations. Besides the fact of who is speaking, it is important to rethink the intermediary role of the media. Newswire services are selective and concentrate on those statements and stories that meet the preferences of the public. This becomes obvious by comparing the impact of statements of the heads of the troika institutions, namely Draghi, Lagarde and Barroso, and statements by other relevant representatives of the ECB, the IMF and the European Commission ("troika other"). The estimation results show that the coordinating effect is more than twice as large for the troika heads. Besides the fact that each statement of one of the three people reaches a large audience, we think their relatively sound reputation plays a role as well. As mentioned earlier, it was the speech of Draghi in the summer of 2012 which decisively calmed international financial markets and thus ensured a relaxation in capital market conditions for Europe's crisis countries. The IMF has also built up a strong international reputation for decades, which makes the impact of statements by its managing director likely. For the general public and traders on financial markets, these people represent the faces of the creditors, who play a decisive role in the decision on an aid package for Cyprus. Dijsselbloem was another central person in the negotiations on the rescue package for Cyprus. As head of the Eurogroup, he was the core voice after meetings of the eurozone finance ministers. During the highly-charged weeks in March 2013, Dijsselbloem expressed himself unfortunately about the role of Cyprus as a blueprint for future bailouts and defended the levy on bank deposits as a direct way to ask for a contribution of the banking sector. The public perception of Dijsselbloem's statements is also apparent from the secondary bond market data. Statements by Dijsselbloem lead to a sustained expansion of the bid-ask spreads ("Eurogroup head"). Even one hour after the communication event, a significant effect averaged over all sovereign bond quotations is observable.

In contrast, statements by Cypriot politicians, Draghi and German finance minister Schaeuble have a large coordinating effect on the market. The information provided appears to be interpreted by the market participants in a similar way. This is also true for French politicians. Another interesting aspect is the comparison of statements by the German chancellor, Merkel and her finance minister, Schaeuble. It is the finance ministers who actively participate in the negotiations. Thus, their statements seem to be a more relevant public signal on future interventions. The spread enlarging effects around statements of Merkel should not be over-interpreted, because she expressed herself on Cyprus only during the high phase of negotiations, when a large number of public signals reached the market.

Overall, it becomes apparent that political communication has immediate and quantifiable effects on the short-term quoting behavior of dealers in the secondary bond market. In many cases, bid and ask price quotations converge, which speaks in favor of a coordination effect of public signals in times of crisis. However, this depends largely on both content and originator of the statement.

5.6.2 Microstructure effects of political communication

So far, we have concentrated solely on the limit order book. This allowed us to analyze the immediate effects of political communication on the quoting behavior of dealers. No less interesting is a look at the effects of communication on the microstructure motives behind the quotations, for which we take actual trades into account. Tables C.7 to C.10 present the regression results with respect to Equations 5.2 to 5.7.

The second and third column of Table C.7 show the regression results of the two-way decomposition model of Huang and Stoll (1997) for the periods without any communication events. The combined estimator λ takes the value of 0.081 for the whole sample of 545 sovereign bonds. That is to say, about eight percent of a quote adjustment on the MTS platform is explainable by the information disclosure associated with the last trade. Market microstructure theory suggests that a transaction may reveal price-relevant information either due to better informed investors in the market or a changed perception of inventory holding costs. The small impact of trade-specific factors on dealers' quoting behavior underpins our expectation that almost all price-relevant information on public issuers are publicly and simultaneously available to investors. Trading on private information seems to be rather less important in sovereign bond markets than it is in other financial markets. Concerning the second theoretical component of λ, inventory holding costs, market makers seem to make use of the possibility to actively trade inventory imbalances with other dealers instead of adjusting their quotations to initiate an equilibrating market order. With respect to the issuing government, λ is largest for Austrian (18 percent) and German (21 percent) sovereign bonds. This may be motivated by a relatively small share of MTS in secondary trading of Austrian and German assets. This causes parallel price discovery processes on different platforms, which enlarges the risk of insider trading.[47]

Columns 3 to 5 of Table C.7 present the estimation results of the same model but with political communication as a further explanatory variable. As becomes obvious, γ, i.e. the direct effect of statements on changes in the quote midprice, is fairly low. This is no surprise when we bring the imbalance of quote adjustments and executed transactions to mind. In contrast to other financial markets, transactions of sovereign bonds are of great value, but relatively rare. To create time windows before quote adjustments in which both communication and trading take place, we decided for an interval length of 30 minutes. That is to say, a communication event takes place up to 30 minutes before the quote adjustment under consideration. Under the efficient market hypothesis, all price-relevant information should be already priced in. This has previously been demonstrated by our event study results. More interesting here is the effect of communication on the meaning of the trade. Comparing the estimation results for λ of the specification with and without communication shows that, on average, the impact of microstructure factors is reduced. λ averages 0.2 percent and is not statistically significant at conventional levels. This tendency is observable for almost all country markets. One could argue that the informational role of trading is reduced when price-relevant public signals reach the market. However, things look slightly different when we focus on the results for Belgian, French and Italian

[47]For background information see Chapters 2.6 and 4.3.3.

bonds, which represent the most liquid markets in our sample. The information disclosure associated with the last trade gains in importance. At first sight, this seems confusing. Combining the findings of the event study approach with the microstructure approach, however, could give us a comprehensive picture of the real price impact of political communication. Immediately after an announcement the bid-ask spread reduces in most cases, which speaks in favor of a coordination effect of communication. However, at the moment when the first trade after the announcement occurs, things change. The trade reveals information to dealers about how other market participants assess the informational content of the previous statement. Unfortunately, we are not able to make a clear point on the source of this development (see Columns 7 and 8).

Concerning the effects of political communication on bonds with different maturities, Table C.8 shows that in times without communication, microstructure factors explain 4.6 percent, 4.4 percent and 12.3 percent of the spread of short, medium and long-term bonds, respectively. This confirms the empirical findings of many other studies that compensation for information asymmetry and inventory holding play an important role in trading long-term bonds. The larger share of buy-and-hold investors in the market results in an enlargement of the waiting time to meet a trade-willing counterparty. This may raise the price risk of holding inventory and increases the probability of better informed investors arriving the market. When we take political communication into account, again no direct effect is observable. However, the price-impact of the last trade increases for sovereign bonds with a term-to-maturity below three years.

Tables C.9 and C.10 present the regression results subdivided by topic and speaker. As in our event study approach, we are able to show that the effect of statements emphasizing the systemic relevance of Cyprus is large and significant. The upcoming trade explains 35.7 percent of the subsequent quote adjustment in the market. The same holds true for statements of the heads of the troika institutions ("troika heads" and "Draghi"). After a statement of Draghi, Lagarde or Barroso the upcoming trade explains about 30 percent of the subsequent quote adjustment. In both cases, this seems to be largely driven by information asymmetries in the market. In other words, political communication seems to have a short-term coordination effect on the limit order book, but once a trade takes place, this gives a first real intuition of the expectations of other market participants on the fundamental value of the asset. Subsequently, dealers adjust their quotes to compensate themselves for the risk of trading with better informed investors. The further estimation results show an ambiguous picture. Statements on bank deposit levies as well as the bail-in of bondholders and shareholders increase the price-relevance of subsequent trades, which speaks in favor of growing market uncertainty. The same holds true for statements of Eurogroup members, France and the German finance minister. However, we are not able to make a point on the segmentation of this effect into information asymmetry and inventory holding costs.

To summarize, we are able to show that the informational role of trading may increase after political statements, indicating that the release of public information may raise the risk of information asymmetries and inventory holding in the sovereign bond market.

5.7 Conclusions

Motivated by the observation of an incoherent communication strategy of politicians during the bailout negotiations on Cyprus in 2012-13, this chapter aims to shed light on the effects of political communication on financial markets. Our findings suggest that statements about the Cypriot debt and banking crisis have important repercussions for prices on the largest interdealer market for trading European sovereign bonds. In the course of an event study approach, we find press conferences, speeches, interviews and written statements of political actors to have demonstrable effects on the short-term quoting behavior of dealers. In many cases, bid and ask price quotations converge for up to half an hour, which speaks in favor of a coordination effect of public signals. The effect is largest for statements that are dedicated to breaking the sovereign-bank nexus. In contrast, market liquidity reduces when Cyprus is evaluated as systemically important for the eurozone or when the negotiated ad-hoc measures are expected to become a template for future bailouts. Concerning the originator of the statement, the coordination effect is large for those policymakers who play an active role in bailout negotiations and who enjoy a sound reputation. This holds true especially for the heads of the troika institutions, namely Draghi, Lagarde and Barroso, but also for the German finance minister Schaueble and Cypriot politicians. In contrast, statements by the new head of the Eurogroup, Dijsselbloem, led to a sustained expansion of bid-ask spreads and thus to a deterioration of liquidity conditions for up to one hour.

Changing to a microstructure perspective and taking executed trades into account delivers us an ambiguous picture. In some cases we are able to confirm the event study results. Due to its anchoring effect on market expectations, political communication reduces the risk of insider trading and the price-risk of inventory holding. However, things look different for Belgian, French and Italian debt securities. Here, the informational role of trading increases after political statements. The same holds true for statements emphasizing the systemic relevance of Cyprus, the discussion on bank deposit levies as well as the bail-in procedure. Concerning the originator of the statement, again the troika heads increase the informational role of subsequent trading. The first trade after an announcement seems to reveal price-relevant information to dealers on how other market participants assess the informational content of the statement. This indicates that political communication may raise the risk of information asymmetries and inventory holding in the market.

We conclude that in times of crisis, political communication is an important component of the policy toolkit. Whatever the rescue plan is, it should be spelled out in a clear and transparent way. This is particularly true in a complex entity like the European Monetary Union. Only with a coherent communication strategy expectations of financial market participants are anchored, which is important for market liquidity and financial stability. For a long-lasting effect, a coherent communication strategy is therefore highly recommended.

C Appendix

Table C.1: List of policymakers

Institution/Country	Position	Name
European Commission	President	José Manuel Barroso
	Commissioner for Economic and Monetary Affairs	Olli Rehn
	Commissioner for Internal Market and Services	Michel Barnier
European Council	President	Herman Van Rompuy
European Parliament	President	Martin Schulz
Euro Group	President	Jean-Claude Juncker (until 21.1.2013), Jeroen Dijsselbloem
European Central Bank	President	Mario Draghi
	Executive Board Members	Benoît Cœuré, Peter Praet, Vitor Constâncio, Jörg Asmussen, Yves Mersch
	National Governors	Luc Coene, Ivan Iskrov, Miroslav Singer, Nils Bernstein (until 31.1.2013), Lars Rohde, Jens Weidmann, Ardo Hansson, Patrick Honohan, George A. Provopoulos, Luis Maria Linde, Christian Noyer, Ignazio Visco, Boris Vujčić , Panicos Demetriades (until 11.4.2013), Chrystalla Georghadji, Ilmārs Rimšēvičs, Vitas Vasiliauskas, Gaston Reinesch, András Simor (until 3.3.2013), György Matolcsy, Josef Bonnici, Klaas Knot , Ewald Nowotny, Marek Belka, Carlos Costa, Mugur Constantin Isărescu, Boštjan Jazbec, Jozef Makúch, Erkki Liikanen, Stefan Ingves, Mervyn King, Marko Kranjec
EFSF / ESM	CEO / Managing Director	Klaus Regling
International Monetary Fund	Managing Director	Christine Lagarde
Germany	Chancellor	Angela Merkel
	Minister of Finance	Wolfgang Schäuble
France	President	François Hollande
	Minister of Finance	Pierre Moscovici
Cyprus	President	Dimitris Christofias (until 28.2.2013), Nicos Anastasiades
	Minister of Finance	Vassos Shiarly (until 28.2.2013), Michael Sarris (until 2.4.2013), Charis Georgiades
Greece, Ireland, Italy, Portugal, Spain	Prime Minister	Antonis Samaras, Enda Kenny, Mario Monti (until 28.4.2013), Enrico Letta, Pedro Passos Coelho, Mariano Rajoy
	Minister of Finance	Yiannis Stournaras, Michael Noonan, Vittorio Grilli (until 28.4.2013), Fabrizio Saccomanni, V/'itor Louçã Rabaça Gaspar, Luis de Guindos
Other eurozone members	Prime Minister	Werner Faymann, Elio Di Rupo, Andrus Ansip, Jyrki Katainen, Jean-Claude Juncker, Lawrence Gonzi (until 11.3.2013), Joseph Muscat, Mark Rutte, Robert Fico, Janez Janša (until 12.3.2013), Alenka Bratušek
	Minister of Finance/European Affairs	Maria Fekter, Steven Vanackere (until 8.3.2013), Koen Geens, Jürgen Ligi, Jutta Urpilainen, Alexander Stubb, Luc Frieden, Jean Asselborn, Tonio Fenech (until 11.3.2013), Edward Scicluna, Jeroen Dijsselbloem, Peter Kažimír, Janez Šušteršič (until 24.1.2013), Janez Janša (until 12.3.2013), Uroš Čufer

Notes: Names of the office holders for the period of interest. Statements by Jean-Claude Juncker and Jeroen Dijsselbloem are attributed to their role as Eurogroup head.

Table C.2: Political communication by topic and speaker

		Total	Classifiable	Topic							
				Systemically relevant and contagious		Levy on bank deposits		Bail-in of share-/bondholders		Template for future bail-outs	
				Yes	No	Yes	No	Yes	No	Yes	No
European officials	EC head	8	1	1							
	EC others	22	7	1			2	6			1
	ECB head	8	4	3			2	1			2
	ECB others	57	30	5	6	1	3	6		1	14
	Eurogroup head	43	21	3	1	6	5	3		1	6
	IMF head	9	3					2			3
	Others	8	3	1			1	2			
National representatives	Cyprus	76	16			6	6	2	1	1	
	Germany	48	24	4	5	2	3	12			3
	France	9	5		2		4				1
	Crisis countries	9	7	1	5		1				2
	Other eurozone countries	33	14		4	1	3	6			1
Total		330	135	19	23	16	30	40	1	3	33

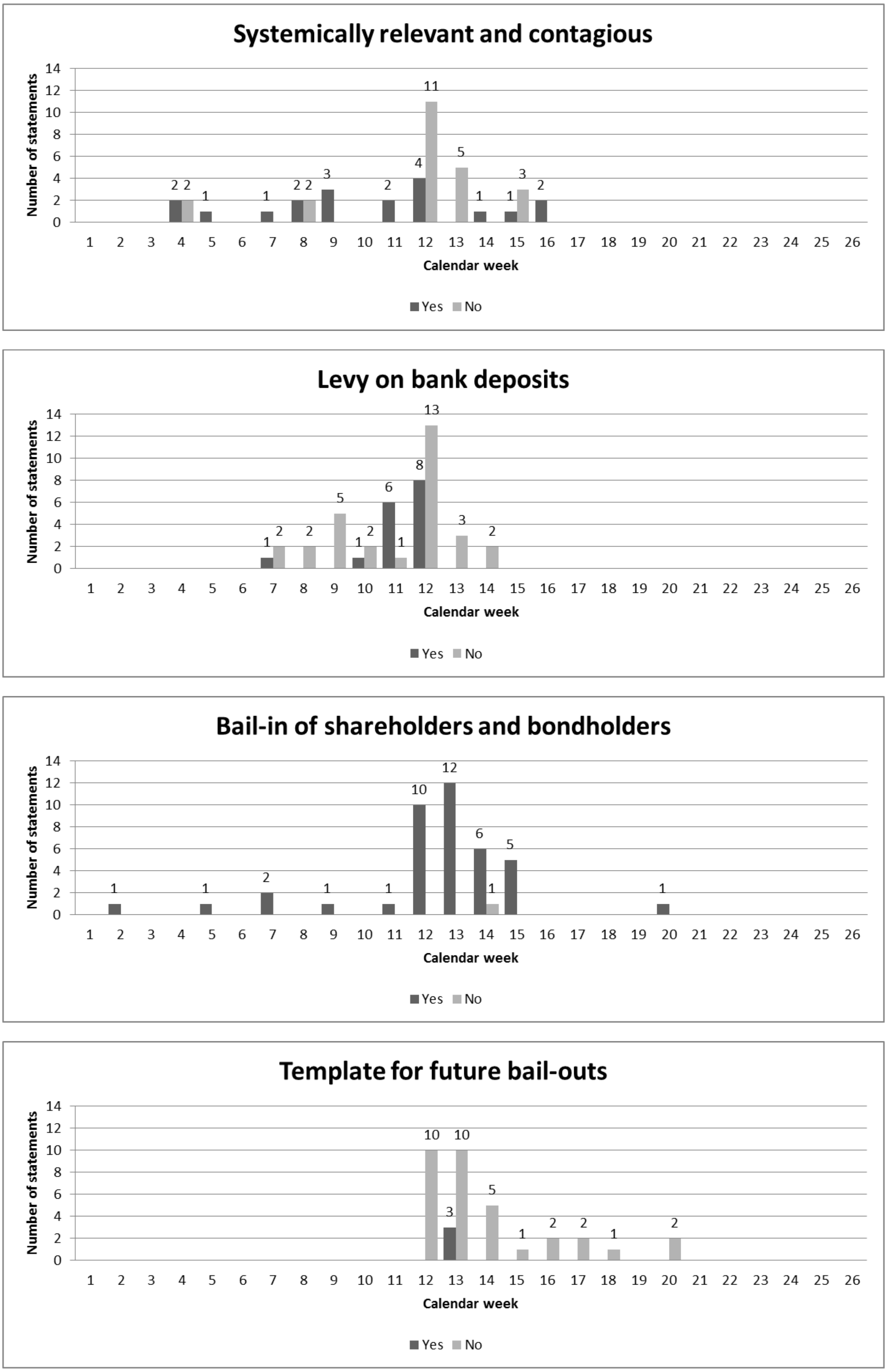


Figure C.1: Political communication by topic and time

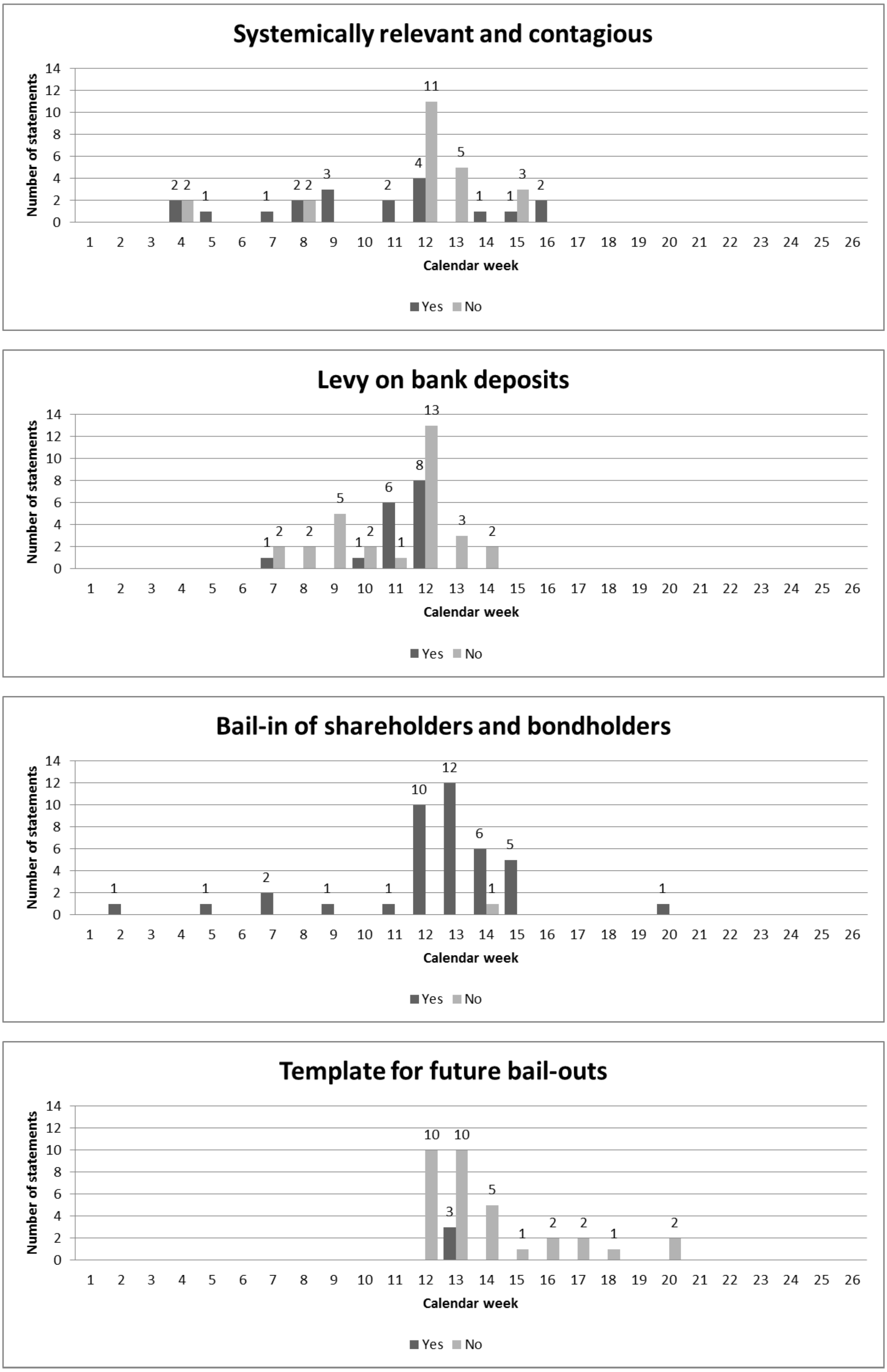


Figure C.1: Political communication by topic and time

Table C.3: Regression results of the event study approach (by issuer country)

	N	t_{-5min}	t	t_{+5min}	t_{+10min}	t_{+15min}	t_{+30min}	t_{+60min}
Austria	2,813	0.002	0.005	-0.008 **	-0.021 ***	-0.014 ***	0.000	0.000
		(0.007)	(0.005)	(0.003)	(0.003)	(0.002)	(0.004)	(0.003)
Belgium	7,115	0.006	-0.002	-0.014 **	0.000	-0.007 **	0.035 ***	0.010
		(0.016)	(0.014)	(0.006)	(0.007)	(0.004)	(0.012)	(0.006)
Germany	7,999	0.009	0.001	-0.016 ***	-0.018 ***	-0.016 ***	-0.007 **	0.000
		(0.009)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Spain	8,068	0.004	-0.003	-0.010 ***	0.008 **	-0.019 ***	0.013 *	0.003
		(0.004)	(0.002)	(0.003)	(0.003)	(0.007)	(0.007)	(0.003)
Finland	1,760	0.014	0.006	-0.014 *	-0.017 *	-0.026 ***	-0.004	0.034 ***
		(0.009)	(0.010)	(0.007)	(0.009)	(0.006)	(0.010)	(0.013)
France	10,424	-0.003	0.003	-0.017 ***	-0.017 ***	-0.019 ***	-0.001	0.007 **
		(0.003)	(0.004)	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)
Ireland	130	0.019	0.007	-0.067	-0.030	-0.014	-0.023	-0.011
		(0.021)	(0.035)	(0.052)	(0.020)	(0.016)	(0.024)	(0.017)
Italy	11,200	-0.013	0.102	-0.584 ***	-0.133 ***	-0.017 ***	-0.020 ***	0.010
		(0.011)	(0.065)	(0.036)	(0.032)	(0.003)	(0.005)	(0.013)
Netherlands	3,402	0.012	-0.003	-0.017 **	-0.010 *	-0.024 ***	-0.007	-0.043 **
		(0.007)	(0.007)	(0.007)	(0.006)	(0.007)	(0.005)	(0.022)
Portugal	255	0.006	0.005	0.011	-0.027	-0.032 *	-0.027 *	-0.046 *
		(0.012)	(0.017)	(0.014)	(0.020)	(0.018)	(0.014)	(0.024)
Slovenia	126	0.009	0.010	-0.012	-0.017 *	-0.011	0.001	-0.011 *
		(0.014)	(0.022)	(0.009)	(0.010)	(0.009)	(0.008)	(0.006)
Total	53,292	0.004	0.022	-0.134 ***	-0.035 ***	-0.017 ***	0.000	0.003
		(0.003)	(0.014)	(0.008)	(0.007)	(0.002)	(0.002)	(0.003)

Notes: The table reports the abnormal bid-ask spread changes to the communication events. Robust standard errors in parentheses. ***, ** and * indicate significance at the 99, 95 or 90 percent level, respectively.

Table C.4: Regression results of the event study approach (by maturity)

	N	t	t_{+5min}	t_{+10min}	t_{+15min}	t_{+30min}	t_{+60min}
< 3 years	17,663	0.031	-0.271***	-0.055***	-0.021***	0.004	-0.003
		(0.039)	(0.021)	(0.020)	(0.003)	(0.005)	(0.008)
3-10 years	22,126	0.038***	-0.081***	-0.031***	-0.017***	0.000	0.009***
		(0.009)	(0.007)	(0.004)	(0.003)	(0.003)	(0.003)
> 10 years	13,503	-0.017	-0.040***	-0.017***	-0.011***	-0.004	0.000
		(0.011)	(0.004)	(0.004)	(0.002)	(0.003)	(0.006)

Notes: See Table C.3.

Table C.5: Regression results of the event study approach (by topic)

	N	t		t_{+5min}		t_{+10min}		t_{+15min}		t_{+30min}		t_{+60min}	
Systemic_pro	4,306	0.256	***	0.191	***	0.020	**	-0.009		0.021		0.001	
		(0.046)		(0.068)		(0.008)		(0.009)		(0.023)		(0.003)	
Systemic_con	4,802	-0.010	***	-0.007	*	0.001		0.002		0.003		0.001	
		(0.003)		(0.004)		(0.002)		(0.003)		(0.003)		(0.004)	
Deposits_pro	2,038	-0.457	***	-0.101	*	-0.113	***	-0.041	***	-0.045	***	0.006	
		(0.085)		(0.051)		(0.022)		(0.012)		(0.008)		(0.005)	
Deposits_con	7,203	-0.021		-0.111	***	-0.029	***	-0.027	***	-0.051	***	0.003	*
		(0.025)		(0.023)		(0.003)		(0.004)		(0.008)		(0.002)	
Bail_in_pro	7,163	0.132	**	-0.224	***	-0.081	***	-0.049	***	-0.089	***	0.002	
		(0.056)		(0.024)		(0.011)		(0.007)		(0.030)		(0.003)	
Template_pro	404	0.141	***	0.020		0.046	***	0.013	*	0.003		0.008	
		(0.052)		(0.017)		(0.010)		(0.007)		(0.005)		(0.009)	
Template_con	6,626	-0.034		-0.180	***	-0.053	***	-0.020	***	0.005		0.000	
		(0.067)		(0.022)		(0.007)		(0.005)		(0.004)		(0.002)	

Notes: See Table C.3.

Table C.6: Regression results of the event study approach (by speaker)

	N	t	t_{+5min}	t_{+10min}	t_{+15min}	t_{+30min}	t_{+60min}
Troika heads	4,431	0.149 *	-0.262 ***	-0.121 ***	-0.058 ***	-0.036 **	-0.030
		(0.088)	(0.036)	(0.016)	(0.008)	(0.015)	(0.014)
Troika other	15,918	-0.025	-0.118 ***	-0.039 ***	-0.020 ***	0.003	0.005
		(0.025)	(0.012)	(0.014)	(0.003)	(0.002)	(0.008)
Eurogroup head	5,810	0.169 **	0.038 *	0.025 **	0.017 **	0.012 *	0.029 *
		(0.069)	(0.020)	(0.011)	(0.008)	(0.006)	(0.015)
Eurogroup other	22,160	0.002	-0.111 ***	-0.084 ***	-0.028 ***	-0.015 ***	0.000
		(0.021)	(0.013)	(0.010)	(0.003)	(0.005)	(0.001)
Cyprus	13,653	-0.018	-0.333 ***	-0.152 ***	-0.031 ***	-0.008	-0.007 **
		(0.033)	(0.023)	(0.016)	(0.004)	(0.008)	(0.003)
Germany	10,599	0.012	-0.200 ***	-0.080 ***	-0.040 ***	-0.007 **	-0.002
		(0.037)	(0.021)	(0.011)	(0.006)	(0.003)	(0.002)
France	1,895	0.078	-0.100 ***	-0.048 ***	-0.038 ***	0.000	0.014
		(0.059)	(0.014)	(0.006)	(0.005)	(0.003)	(0.010)
Merkel	3,435	0.115 ***	-0.110 ***	-0.003	-0.005	0.021	0.003
		(0.032)	(0.024)	(0.011)	(0.003)	(0.014)	(0.010)
Draghi	1,668	-0.100	-0.328 ***	-0.208 ***	-0.021 ***	-0.008	-0.008 **
		(0.080)	(0.054)	(0.036)	(0.005)	(0.006)	(0.003)
Schaeuble	7,509	-0.036	-0.232 ***	-0.110 ***	-0.054 ***	-0.009 **	-0.008 ***
		(0.051)	(0.028)	(0.015)	(0.008)	(0.004)	(0.002)

Notes: See Table C.3.

Table C.7: Regression results of the microstructure approach (by issuer country)

	No communication Two-way model			Communication Two-way model					Communication Three-way model			
	N	λ		N	λ		γ		α		β	
Austria	1,317	0.180	***	47	0.169	*	-0.002		0.496	**	-0.171	*
		(0.028)			(0.099)		(0.011)		(0.204)		(0.096)	
Belgium	8,475	0.030		582	0.206	**	0.000		0.276		-0.044	
		(0.021)			(0.104)		(0.001)		(0.204)		(0.075)	
Germany	3,693	0.212	***	186	0.130		-0.005		-0.125		0.203	*
		(0.036)			(0.161)		(0.004)		(0.209)		(0.107)	
Spain	6,733	0.052	**	463	-0.009		0.001		-0.133	*	0.092	***
		(0.024)			(0.054)		(0.003)		(0.077)		(0.033)	
Finland	1,477	0.062	***	100	-0.009		0.000		0.056		-0.062	
		(0.020)			(0.062)		(0.002)		(0.070)		(0.053)	
France	7,575	0.049	***	521	0.088	**	-0.005	*	-0.023		0.108	*
		(0.015)			(0.044)		(0.002)		(0.048)		(0.056)	
Ireland	333	0.111	**	15	0.095		0.011		0.342		-0.055	
		(0.044)			(0.314)		(0.049)		(0.288)		(0.271)	
Italy	34,208	0.112	***	1,975	0.151	***	0.000		0.076	*	0.062	**
		(0.009)			(0.037)		(0.001)		(0.045)		(0.025)	
Netherlands	5,544	0.055	**	363	0.034		0.004	***	0.002		0.038	
		(0.028)			(0.028)		(0.001)		(0.052)		(0.027)	
Portugal	675	0.090	*	55	-0.213	**	-0.022		-0.148	**	-0.060	*
		(0.051)			(0.098)		(0.022)		(0.070)		(0.034)	
Total	70,030	0.081	***	4,307	0.002		0.000		0.032		-0.018	
		(0.017)			(0.066)		(0.001)		(0.025)		(0.049)	

Notes: The table reports the changes in the quote midpoint to the communication events. Robust standard errors in parentheses. ***, ** and * indicate significance at the 99, 95 or 90 percent level, respectively.

Table C.8: Regression results of the microstructure approach (by maturity)

	No communication Two-way model			Communication Two-way model				Communication Three-way model			
	N	λ		N	λ		γ	α		β	
< 3 years	32,625	0.046	*	2,281	0.121	**	0.000	-0.240	***	0.322	***
		(0.026)			(0.051)		(0.001)	(0.086)		(0.084)	
3-10 years	27,010	0.044	**	1,515	0.053		0.000	0.007		0.061	
		(0.018)			(0.043)		(0.001)	(0.104)		(0.113)	
> 10 years	10,395	0.123	***	511	-0.017		-0.002	0.122		-0.127	
		(0.022)			(0.082)		(0.005)	(0.185)		(0.231)	

Notes: See Table C.7.

Table C.9: Regression results of the microstructure approach (by topic)

	No communication Two-way model		Communication Two-way model			Communication Three-way model	
	N	λ	N	λ	γ	α	β
Systemic_pro	74,034	0.077 ***	303	0.357 ***	0.001	0.217 ***	0.050
		(0.016)		(0.118)	(0.003)	(0.064)	(0.077)
Systemic_con	74,044	0.077 ***	293	0.081	0.001	-0.012	0.070
		(0.016)		(0.104)	(0.002)	(0.065)	(0.046)
Deposits_pro	74,267	0.077 ***	70	0.066 *	-0.024 *	-0.091	0.149 *
		(0.016)		(0.035)	(0.013)	(0.066)	(0.088)
Deposits_con	73,755	0.077 ***	582	0.060 *	-0.004	0.013	0.038
		(0.016)		(0.032)	(0.003)	(0.037)	(0.037)
Bail_in_pro	73,811	0.077 ***	526	0.190 ***	0.001	0.257	0.013
		(0.016)		(0.054)	(0.001)	(0.156)	(0.036)
Template_pro	74,253	0.077 ***	84	-0.222	-0.001	-0.141	-0.153
		(0.016)		(0.196)	(0.003)	(0.157)	(0.114)
Template_con	73,966	0.077 ***	371	0.078	-0.001	0.062	0.046
		(0.016)		(0.055)	(0.002)	(0.041)	(0.030)

Notes: See Table C.7.

Table C.10: Regression results of the microstructure approach (by speaker)

	No communication Two-way model			Communication Two-way model					Communication Three-way model			
	N	λ		N	λ		γ		α		β	
Troika heads	74,016	0.077	***	321	0.289	***	0.004		0.269	***	0.023	
		(0.016)			(0.093)		(0.003)		(0.066)		(0.064)	
Troika other	73,179	0.080	***	1,158	-0.134		-0.001		0.170	**	-0.150	***
		(0.016)			(0.118)		(0.001)		(0.079)		(0.051)	
Eurogroup head	73,745	0.077	***	592	0.084	*	-0.002		0.022		0.058	*
		(0.016)			(0.043)		(0.003)		(0.037)		(0.032)	
Eurogroup other	72,758	0.077	***	1,579	0.079	*	0.000		-0.057		0.103	***
		(0.016)			(0.044)		(0.001)		(0.071)		(0.025)	
Cyprus	73,290	0.078	***	1,047	0.037		0.001		-0.062		0.064	
		(0.016)			(0.064)		(0.002)		(0.093)		(0.041)	
Germany	73,690	0.077	***	647	0.065		0.003	*	0.106		-0.008	
		(0.016)			(0.058)		(0.002)		(0.085)		(0.035)	
France	74,184	0.077	***	153	0.414	**	0.001		0.044		0.156	
		(0.016)			(0.186)		(0.001)		(0.122)		(0.132)	
Merkel	74,109	0.078	***	228	-0.105		0.004		-0.016		-0.040	
		(0.016)			(0.091)		(0.003)		(0.081)		(0.038)	
Draghi	74,229	0.077	***	108	0.320	**	-0.002		0.231	***	0.073	
		(0.016)			(0.146)		(0.007)		(0.087)		(0.088)	
Schaeuble	73,899	0.077	***	438	0.154	*	0.003		0.121		0.054	
		(0.016)			(0.084)		(0.002)		(0.104)		(0.040)	

Notes: See Table C.7.

6 Did the EU summits succeed in convincing the markets during the recent crisis?[48]

Abstract

Using an event study approach, this chapter examines whether crisis meetings of European heads of state and government, as well as their agreed and communicated results, had a significant impact on financial markets. The analysis is based on daily data for seven member states of the eurozone (France, Germany, Greece, Ireland, Italy, Portugal and Spain), starting in September 2008 and covering the time period until April 2012. We find the high-profile meetings to have only minor effects that ceased quickly. Only Germany was able to profit from sustainably better market conditions after meetings. As opposed to this, first and foremost Greece faced partly severe negative effects. We conclude that investors consider Europe's economic and political crisis management insufficient and its communication strategy little convincing. While controlling for additional effects, we show that conventional and unconventional policy measures taken by the ECB have had short-run effects on bond returns and the exchange rate, but none of the intended influence on stock prices, with the exception of Italy.

6.1 Introduction

After the demise of Lehman Brothers in autumn 2008, the financial crisis spread extensively to Europe. It was notably followed by a deceleration in economic activity in 2009, with negative growth rates that were the largest in many countries since

[48]The article, on which this chapter is based, is co-authored by Prof. Dr. Heinz-Dieter Smeets and has been published in *Journal of Common Market Studies, Vol. 51, No. 6, November 2013, pp. 1158-1177.*

the Great Depression in the 1930s. The third stage of the crisis began early in 2010 when Greece—later followed by Ireland and Portugal, and more recently Italy and Spain—came under pressure from exploding sovereign debt, the persistent instability of its financial sectors and a further slowdown in economic activity. With the intention of avoiding contagion and reducing uncertainty in the markets, European heads of state and government agreed to provide financial assistance of more than EUR 800 billion up to date, establish stricter rules for national budgets, and enhance the conditions for growth and structural reforms. Against this background, European crisis management has become a matter of highest political priority and the key instrument for policy coordination among European leaders.

The practice of intergovernmental policy coordination is not a new development in the Union's (largely) decentralized system of political responsibilities (Puetter, 2011). However, since the onset of the recent turmoil, it has become established as the predominant strategy in day-to-day crisis management. As a consequence, the public pressure on European leaders to agree upon convincing measures has dramatically increased, yet in contrast to these expectations the success of measures having been agreed upon up to now is highly debated. Results are typically communicated at the end of the meetings and may contain information, for instance, on the future strategy in handling the crisis and the agreements on (new) policy measures. Therefore, the meetings of the European heads of state and government can be interpreted as "events" whose (economic) impact is assessed by analyzing the reaction of financial market participants to this news.

Event studies have a long tradition in empirical economics and were applied to a wide field of different issues comprising mergers (Eckbo, 1983, Eckbo and Wier, 1985, Duso et al., 2007), free trade areas (Thompson, 1993, 1994, Rodriguez, 2003, Moser and Rose, 2014) and foreign exchange interventions (Fatum and Hutchison, 2003, Jansen and de Haan, 2005, Fratzscher, 2006, 2008, Ehrmann and Fratzscher, 2007, Kohn et al., 2003). Until now, however, the impact of meetings of the European heads of state and government has not been analyzed in this context. So far, there has been only one crisis-related study by Mink and De Haan (2013) which deals with the signaling effects of news about the economic situation of Greece and Greek bail-outs that focuses on contagion between European banks and member states. The authors conclude that the return on sovereign debt—particularly in Portugal, Ireland and Spain—responded significantly to such news, which may display contagion.

A (loosely) related strand of literature concerns central bank communication and credibility. Valuable reviews are provided by Blinder et al. (2008), Eijffinger and van der Cruijsen (2007) and Blattner et al. (2008). Given that communicated information can be interpreted as an event, these studies share some similarities with our own analysis. One must bear in mind, however, that communication in this field of research is interpreted as an additional "oral" instrument compared to monetary policy in the narrow sense. Results that are of particular interest to our own study are the following: (i) More and better central bank communication contributes to an increased predictability of (monetary) policy; (ii) predictability appears to be degraded when central bankers speak with too many conflicting voices and (iii) disclosing central bank views on, for example, the outlook for the economy as well as future strategies and policies has consistent ("right") impacts on financial markets.

Against this background, this chapter focuses on the signaling effects of EU leaders' meetings and the persuasiveness of their results. The event study approach applied here is based on the non-parametric sign test and the matched sample test in order to examine the effectiveness of these high-level meetings in influencing financial markets—particularly the impact on general and financial stock prices, return on government bonds and exchange rates. The focus is on the most crisis-ridden member states of Greece, Ireland, Italy, Portugal and Spain, as well as the largest economic members of the eurozone: France and Germany. The results reveal that meetings of the heads of state and government and their political statements had, in general, only a small and temporary impact. The member states' stock prices show positive development during the first trading day after a meeting for almost all of the countries involved. However, in most cases this effect dries up during the ensuing days. Regarding the return on government bonds, only Germany profited from better (re-)financing conditions after summits. Similar results hold for the euro exchange rate against the American dollar, which shows that there is only limited evidence of any longer-term impact of the meetings after an immediate appreciation of the common currency. To control for any further influences we performed an additional analysis—although less profound—of European Central Bank (ECB) policy. Concerning the purchase of government bonds by the ECB, only a short-term but insignificant decrease in their returns was observed. However, interest rate and liquidity policy by the ECB gave expected and significant effects only on the return of German government bonds and the exchange rate. All ECB measures observed here did not show any expected effects on stock prices, with the exception of Italy.

The chapter proceeds as follows: Section 6.2 provides a short description of the data, while Section 6.3 introduces the specific event study methodology. Section 6.4 presents the estimation results and robustness checks. The final section, 6.5, contains the conclusions.

6.2 Data description

The events of interest are, first and foremost, the formal and informal meetings of the European heads of state and government in the form of the European Council and the newly established Euro summits.[49] According to the presidency conclusions and press releases, the recent crisis has been part of the agenda from autumn 2008 onwards. Therefore, the analysis covers the time period from September 1, 2008 to April 30, 2012. An overview of all meetings is provided in Table D.1 in the Appendix. Before the crisis, Council meetings usually took place four times a year in Brussels. Since the onset of the crisis, however, the frequency of meetings has doubled. During the complete sample period, the heads of state and government met 28 times: 16 meetings were formal European Council meetings, seven informal European Council meetings, one extraordinary meeting and a further five meetings of only the heads of state and government of the member states of the eurozone. While the crisis as a whole started in autumn 2008, the associated eurozone sovereign debt crisis only emerged early in 2010. Since then, private (re)financing has become

[49]Eurozone leaders first met as an autonomous group in October 2008 when the financial crisis spread extensively to Europe. After a number of ad hoc meetings it was agreed to formalize the summits, and since then, they have met regularly twice a year.

increasingly harder for Greece and the financial markets have started to focus on the eurozone periphery. Therefore, in addition to the complete sample period, a sub-sample starting on January 1, 2010 is also examined. Analyzing these two time periods allows us to consider whether the financial markets were hit differently during the various stages of crisis.

The predominant, common objective of all EU summits and measures agreed upon (in all phases of the crisis) has, in our opinion, been to create confidence in the eurozone as a whole, and especially regarding economic performance. This holds true even for summits focusing on long-term planning and future crisis prevention. Since 2010 this principal objective has been supported by the ECB, particularly in its purchasing of government bonds of crisis countries in the secondary markets. Confidence in the eurozone, as well as the provision of financial assistance for highly indebted countries, should, in turn, reduce the return on government bonds, thereby avoiding contagion and stabilizing the real economy; while perhaps also preventing the euro from falling in value. The main financial "indicators" reflecting the (short-term) effects of these policies are, therefore, the return on government bonds, stock prices and the exchange rate.[50] At the same time, the "normal" monetary policy of the ECB could be observed, the conduction of which was primarily to stabilize the real economy. This policy may, however, further influence the return on government bonds as well as the exchange rate via the monetary transmission channel. These relationships are summarized in Figure 6.1.

Against this background, the analysis focuses on three financial markets and on the corresponding (excess) returns which are expected to be influenced by event-related information. First, we examine stock prices (s_j) since the real economy and especially the financial sector are expected to be hit during all stages of the crisis. Second, the return on (ten-year) government bonds (i_j) is considered, which attracted great attention during the sub-sample starting early in 2010, when diminishing and increasingly expensive (re-)financing opportunities for more and more member states occurred. Finally, we analyze the euro exchange rate against the American

[50]High-frequency financial data are typically used as an "intermediate target" to capture long-term (communication) effects on macroeconomic variables well in advance (Blinder et al., 2008).

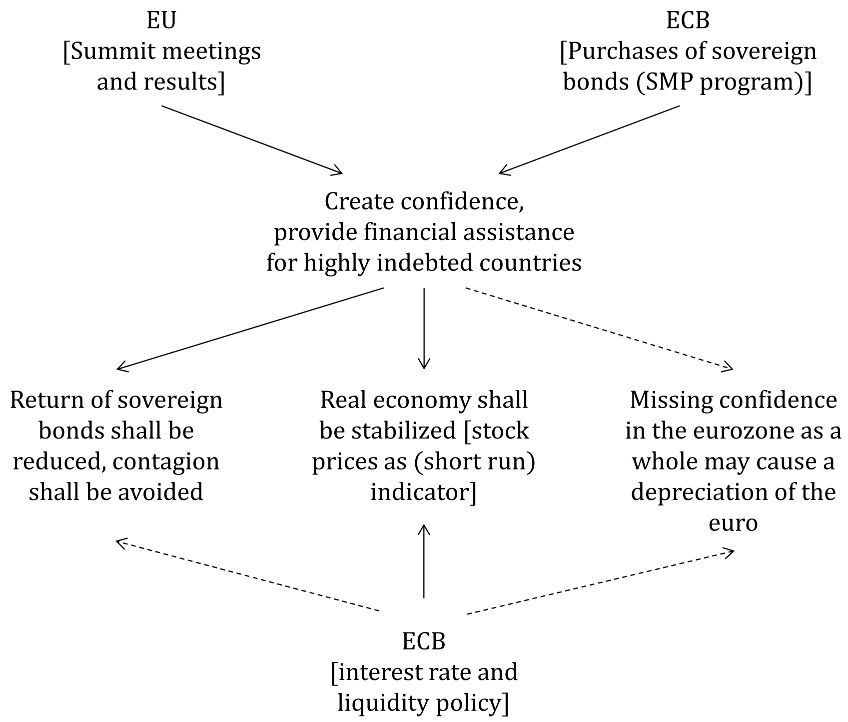


Figure 6.1: Crisis policy and financial indicators

dollar (e) as an indicator for the international standing of the eurozone. This gives a good indication of whether the current turmoil is evaluated by market participants as a crisis due to budgetary and economic problems of a few member states or as a systemic crisis of the eurozone in its entirety. To control for any additional effects, we also analyze measures taken by the ECB. According to Figure 6.1, a distinction is drawn between the purchase of government bonds and "normal" interest rate and liquidity policy.

Daily data for the underlying time-series were obtained from Thomson Reuters ECOWIN. Since our focus is on the idiosyncratic national component of the series, it is necessary to adjust national returns for a common European or international drift. In particular, excess returns take into account the following benchmark series: EURO STOXX 50 as the reference index for European stock prices, the Euro InterBank Offered Rate (EURIBOR) as the eurozone-wide (risk-free) interest rate and the Nominal Effective Exchange Rate (EER-20) as indicator for the global euro exchange rate trend. Due to the high frequency of events it is not possible to calculate the excess returns by estimating a market model regression as the number of observations between events is too small. Instead, it is calculated as the simple difference between the national series and the corresponding (European) benchmark series.

6.3 Event study methodology

An event study is an empirical approach to estimating the impact of a given type of event (predominantly) on financial markets. If we assume that markets process information in an efficient and unbiased manner, the basic idea is to link excess returns to the events of interest by comparing the pattern of financial market movements during a pre- and post-event period. This section therefore defines the relevant events and the associated pre- and post-event windows. Following these preliminaries, we will define criteria to evaluate whether or not an event can be regarded as a success.

One intuitive approach to define the events of interest is to consider each meeting of the heads of state and government as a separate event. Starting with the crisis, however, an increasing number of meetings have become necessary to coordinate actions. Since we are interested in an evaluation of the developments on the financial markets surrounding each meeting—that is, in a comparison of the movements before and after an event—closely spaced summits can be associated with overlaps of the respective pre- and post-event windows and might thus cause results to be distorted. In order to overcome such biases, some meetings are clustered together into one event. This is the case in October 2008 when the heads of state and government of the eurozone held their “emergency summit” three days before the formal European Council meeting took place. The same holds true for October 2011 when the formal meeting of all 27 leaders was accompanied by the Euro summit three days later. Thus, between September 2008 and April 2012, 26 events were identified, of which one event covers a period of five days, one a period of four days and 12 the regular period of two days. The President of the European Council, Herman Van Rompuy, prefers to restrict the summits to a single day, and so the remaining 12 meetings were single-day events (Banks, 2010). Apart from the overall observation period, this chapter focuses on a sub-sample of 16 events from January 1, 2010 onwards.

In addition to these summits, ECB policy measures were taken into account as previously explained. For the interest rate and liquidity policy, we include all 11 alterations of key interest rates (nine of which are reductions) and the two 36-month longer-term refinancing operations ("Big Berthas") that fell into our sample period(s). Since the purchase of government bonds is not known by the exact date and is more of a continuous process, we identified six dates at which purchases—according to newspaper reports—increased markedly. All dates are shown in Table D.1.

Aside from the definition of the events, the number of relevant trading days before and after each meeting must be determined. The aim is to compare the movement of returns after a meeting with those prior to the meeting, and to identify whether an event provides relevant news to the markets that is reflected in statistically significant abnormal (excess) returns. To check for the robustness of results pre- and post-event window lengths of two, five, ten and 15 days were applied. Furthermore, this method provides an opportunity to evaluate the impact of meetings over various time horizons: the longer the window length, however, the larger the risk of having other (non crisis-related) news arriving and influencing the results.

The event study approach reduces the dimensions of financial market evolutions by distinguishing solely between whether an event is successful or not in influencing the markets. Therefore, we define and apply five (partly complementary) success criteria (Fatum and Hutchison, 2003) that evaluate or compare average (excess) returns over the windows before ($t-$) and after ($t+$) the event.[51]

As a first criterion, a basic and very short-run measure is applied by simply examining whether returns moved in the desired direction the first trading day after a meeting. Therefore, the closing value at $t+1$ is compared with the closing value at t. Since we expect politicians to aim at increasing stock prices and decreasing returns on sovereign bonds, while having no special preference for the exchange rate movement,[52] under the *short-term criterion*, success is formally defined as follows:

$$(i_j^{t+1} < i_j^t); \;\; (s_j^{t+1} > s_j^t); \;\; (e^{t+1} > e^t). \tag{6.1}$$

[51] Returns on stocks and on the exchange rate are calculated as the daily percentage changes of the respective prices.

[52] The exchange rate is quoted as the foreign currency per unit of the domestic currency. Equation 6.1 elucidates that the criterion for the exchange rate movement assumes an appreciation as a "success".

Working from the premise that efficient financial markets should react only to news, we also apply this short-term criterion to test—at least partially—for expectations or anticipation effects ahead of the EU summits. Assuming that the structure of these effects is basically unknown, we apply the short-term criterion to the day before the event in order to capture at least some of these effects.

All remaining criteria are based on average excess returns (Δer) as defined above. Accordingly, the *direction criterion* defines a successful event as one where the movement of the average excess return over the post-event window is consistent with the objectives of the heads of state and government or the ECB as previously stated. Therefore, success is formally defined as follows:

$$(\Delta er(i)_j^{t+} < 0);\;\; (\Delta er(s)_j^{t+} > 0);\;\; (\Delta er(e)^{t+} > 0). \tag{6.2}$$

The *smoothing criterion* is less demanding in its definition of success. It solely requires the return movements after the event to be more advantageous compared to those before the meeting. In this case, success is formally defined as follows:

$$(\Delta er(i)_j^{t+} < \Delta er(i)_j^{t-});\;\; (\Delta er(s)_j^{t+} > \Delta er(s)_j^{t-});\;\; (\Delta er(e)^{t+} > \Delta er(e)^{t-}). \tag{6.3}$$

If there is, on average, an unfavorable trend in the development of the excess return before the event, the *reversal criterion* examines whether—for the corresponding sub-set of events which satisfies this condition—this trend could be reversed. Under this criterion, success is formally defined as follows:

$$\begin{aligned}
&(\Delta er(i)_j^{t+} < 0 \;\;\wedge\;\; \Delta er(i)_j^{t-} > 0);\\
&(\Delta er(s)_j^{t+} > 0 \;\;\wedge\;\; \Delta er(s)_j^{t-} < 0);\\
&(\Delta er(e)^{t+} > 0 \;\;\wedge\;\; \Delta er(e)^{t-} < 0).
\end{aligned} \tag{6.4}$$

Finally, the *volatility criterion* evaluates whether the event-related economic results reduce the swings of the pre-event movements and thus calm the markets. Here, the approach of Jansen and de Haan (2007) is followed by applying squared excess returns to determine volatility. With this considered, success is formally defined as follows:

$$
\begin{aligned}
(\Delta er(i)_j^{t+})^2 &< \Delta er(i)_j^{t-})^2; \\
(\Delta er(s)_j^{t+})^2 &< \Delta er(s)_j^{t-})^2; \\
(\Delta er(e)^{t+})^2 &< \Delta er(e)^{t-})^2.
\end{aligned}
\tag{6.5}
$$

To determine whether the results are random or systematic, two tests are applied. First, the non-parametric *sign test*, which has very general applicability since it does not require any specific assumptions concerning the distribution of returns. Although starting from the initial assumption that the probability of success (p) is equal to 0.5, individual p-values were subsequently calculated for each country, time period, criterion and window length, respectively, using the non-event cases as the control sample. The individual results are tested against the hypothesis that $p = 0.5$. In all cases where the hypothesis is rejected, we base the sign test on estimated p-values.[53] A significant sign test rejects the null hypothesis stated below and indicates that the observed number of successful events (ev^+) is significantly larger than the number of unsuccessful events conditional on:

$$
ev^+ \sim binomial(ev, p) \tag{6.6}
$$

with ev being the total number of events.[54]

In addition to the sign test, the *matched sample test* (Cochran, 1950) is applied. This test statistic is also designed to infer a significant shift between the average movement of excess returns during the pre- and the post-event periods. However, it is not constrained to test for a particular (positive or negative) sign of the abnormal returns given by the success criteria as previously defined. Instead, the test statistic itself reveals the “correct” sign, which is not constrained by a success criterion in advance. The null hypothesis states that there is no difference in the means before and after an event. For each observation (event) of the first sample (pre-),

[53] A general tendency can be observed in that p-values concerning the short-term and the direction criterion show an increase with the window length for Germany and France towards 0.6, while showing a decrease towards 0.3 for the most crisis-ridden countries. For all other criteria, in most cases p does not deviate significantly from 0.5.

[54] For details concerning this test, see MacKinlay (1997).

the associated or matched value of the second sample (post-) is obtained and the individual differences calculated. The overall sample mean (D) and the standard deviation (s_D) are calculated as usual. Assuming that the values from both samples are normally distributed, the test statistic follows a t-distribution with $n-1$ degrees of freedom where n is the number of paired observations. Formally expressed, the test statistic is given by:

$$\frac{D-\mu_D}{s_D} \sim t(n-1) \tag{6.7}$$

where μ_D is the mean value of the difference under the null (which is zero in our case).

While the matched sample test assumes a normal distribution of the underlying series, there is substantial evidence that (daily) financial time series exhibit a high degree of "fat tails". To avoid biased test results due to this occurrence, t-statistics are computed by regressing the differences of the matched pairs on a constant term using White's (1980) heteroscedastic-consistent standard errors. The estimated constant term is equivalent to the difference in the mean values prior to and after the event (Fatum and Hutchison, 2003).

6.4 Empirical results

Concerning first the impact of the summit meetings and their economic results on the member states' general stock prices, Table D.2 displays the corresponding results of the short-run analysis, the four additional sign test results based on the success criteria defined above as well as the matched sample test results. It is expedient to begin with stock prices, as the stabilizing of the real economy, and the financial sector in particular, was a key intention behind the EU summits during both periods considered. In this regard, France and Germany show the most significant results. France shows a positive but very short-term effect during the sub-sample concerning the sovereign debt crisis as well as a direction effect during the overall sample. This outcome is—for the second phase—confirmed by the results of the matched sample test. Germany also exhibits significant effects for both the direction criterion in addition to some other criteria covering both periods. For all other countries, there are rarely any significant results that show any increase in stock prices independent of the criterion and sample period. In many cases the matched sample test even demonstrates a negative sign, thereby reflecting a lack of confidence rather than the expected reverse. The worst case in this regard is Greece, which exhibit a negative sign in all cases, even if it is not significant.

As far as availability allows, the results for financial stock prices are presented in Table D.3. Again, there is nearly no significant sign test result. However, the matched sample test reveals that—with particular regard to Greece and Ireland—this result is due to a decrease in the average excess returns after summits, which are directional opposites compared to the defined success criterion. This is particularly the case for the second time period. For Spain, however, there is no significant result evident. The reason for this may be that Spain only became a crisis country towards the end of our sample period.

Table D.4 presents the results concerning the (average) excess return on ten-year government bonds. With a focus on the very short-run impact of the meetings, only Germany shows a significantly lower return on the first trading day after an event. This result is confirmed by the matched sample test which shows that the German government—particularly during the sub-sample starting 2010—were required to pay significantly lower interest rates on their debt after events. Since a decrease in sovereign bond returns was defined as a success, it is unsurprising that for all other countries in the sample no significant sign test results occur. The matched sample test again shows that most other governments faced higher financing costs for their debt. France, Italy, Spain and Portugal exhibit results with positive signs of the differences in means, which are significant as far as the whole period is observed. Regarding Greece, however, for the two-day window the test shows a negative sign, which implies a success, whereas for the other window widths significant results with positive signs (failure) were found.

Table D.5 displays the results concerning the impact of the meetings on the euro exchange rate against the American dollar. During the very short term there is no impact on the exchange rate to be observed. With concern to the other four sign criteria, some point to an appreciation after summits even for wider windows. Moreover, throughout the sub-period starting in 2010, events may have succeeded in reducing exchange rate volatility over the two-day window. However, all results are, at best, significant at the 90 percent level. While the matched sample test confirms these findings by showing a positive sign, all corresponding results show very small coefficients and lack significance. This may nevertheless point to the fact that market participants assess the recent turmoil (particularly in the second phase) less as a crisis of the eurozone and the euro itself, but rather much more as a crisis of some highly indebted member countries. For all countries and indicators, no significant anticipation effects could be detected.

Finally, effects of policy measures applied by the ECB are compiled in Tables D.6 and D.7. Due to the scope of the present study, only outcomes for a sub-sample of (the most affected) countries are reported. Moreover, the effects of interest rate and liquidity policy are exclusively estimated over the complete sample period, while only the sub-sample starting in early 2010 is of interest for purchases of government bonds. Finally, the different types of events were deliberately not aggregated in order to prevent diluting the outcome of EU summits, which are our central point of interest.

As far as the purchase of government bonds is concerned, Table D.6 displays no significant decreases in their return. However, for those countries in which bonds were bought most and to the greatest extent—Greece, Italy and Spain—the results of the matched sample test reveal that a short-term success (negative but insignificant result) could be observed, which ceased quickly and, in the case of Greece, reversed after a few days. A significant increase in general stock prices occurred in Italy alone, while financial stock prices showed no significant reaction in any of the cases observed. Consequently, results are not reported in Table D.6. These results again prove that official market interventions have, in the majority of cases, no lasting effect on the corresponding prices until private market participants expect a confident change in policy. A short-run depreciation of the exchange rate, observable from the matched sample test (although not significant), may primarily reflect the increased liquidity available rather than lost confidence in the eurozone and the common currency. However, the outcome is observed to change into the reverse again after a few days.

As only six events are taken into account, it is problematic to arrive at any significant outcomes. Results concerning purchases of government bonds would, therefore, be better interpreted as a rough intuition of possible effects.

Interest rate and liquidity policy by the ECB presents only a significant short-term effect on the German bond rate (Table D.7). However, similar to the other countries analyzed, this short-term decrease eventually turns into a significant increase over the course of time. The reason for this result is that the matched sample test is based on excess returns which increased during the first phase of the crisis due to sharply decreasing short-term interest rates (including EURIBOR), while during the second phase the bond rates of the crisis countries correspondingly increased. For the first phase, this reflects the successful working of the liquidity effect of monetary policy. Conversely, these policy measures did not show any significant success in the form of an increase in stock prices. The significant decrease in the exchange rate is, in turn, the expected reaction to an expansionary monetary policy being predominantly executed throughout the whole of the considered sample. For all ECB measures, no significant anticipation effects could be detected.

6.5 Conclusions

Since the onset of the current crisis, multilateral meetings of European leaders have been at the forefront of public interest. In applying an event study approach it was possible to analyze whether the crisis meetings of European heads of state and government, and agreed results, had a significant impact on Europe's financial markets, and thus on the conditions faced by the member states' public sector, real economy, banking sector and the common currency. The analysis is based on daily data for the most crisis-ridden member states—namely Greece, Ireland, Portugal, Italy and Spain—and the largest economic members France and Germany, starting with the global financial and economic crisis in autumn 2008 and lasting until April 2012.

To summarize our findings, the high-profile meetings seem to have little conclusive effect on the financial markets. Regarding the countries' real economy, the cases with an increase in the general stock prices following EU meetings are mainly confined to France and Germany. Conversely, financial stock prices in Greece and Ireland decreased significantly. Concerning the risk premium on ten-year sovereign bonds, only the German government was able to profit from (sustainably) better (re-)financing conditions after meetings, while all crisis countries as well as France experienced a significant increase in their risk premiums. Finally, for the euro vis-à-vis the American dollar no significant effects could be detected. Thus, market participants seem to assess the debt crisis much more as a crisis of some highly indebted member countries rather than as a euro crisis. Overall, one can conclude that investors generally consider Europe's economic and political crisis management insufficient and its communication strategy little convincing.

Similarly, ECB policy measures display only a few intended and significant effects. Stock prices—which may best reflect the main goal of interest rate and liquidity policy, to create confidence in the real economy and the banking sector—did not increase significantly for both the general and the financial benchmark indexes. Results concerning purchases of government bonds by the ECB point merely to some short-term influence on bond prices which, however, ceases quickly and lacks significance in most cases. A short-term depreciation of the exchange rate reflects mainly effects arising from an increased liquidity in the eurozone due to the overall expansionary monetary policy.

The literature on central bank communication may shed some light on the question of why EU summits had little impact on financial markets during our sample period. One reason might be that information about the economic outlook for, and future policies towards, (crisis) countries can only influence financial markets to go in the "right" direction if the information itself is consistent. However, forecasts of organizations such as the International Monetary Fund (IMF) or European Union (EU) are very often biased in favor of the country concerned in order to legalize ongoing support (Aldenhoff, 2007, Dreher et al., 2008). This phenomenon could also be observed during the current crisis and may have reduced confidence in these organizations and their forecasts as well as policy measures based thereon. Moreover, heads of state and government have had differing ideas of how to cope with the crisis, which has led to many conflicting voices. This may also cause the lack of any significant anticipation effects prior to the meetings as market participants were unable to obtain consistent information in advance. A further argument accounting for missing significance of our results could lie in the decentralized structure of EU decision-making. Since results of summit meetings must—at least in certain cases—be ratified by national parliaments, it is only these final outcomes (at a later point in time) that may reflect the relevant news. Finally, one must bear in mind the fundamental differences between central banks and EU summit meetings: the former communicate mostly about well-known and commonly accepted targets and instruments (Woodford, 2005). Furthermore, they may have already built up a sound reputation on which existing confidence is based. Both these arguments in favor of central banks do not, or at best to a minor extent, apply to EU summit meetings.

D Appendix

Table D.1: Events between October 2008 and April 2012

Date	Type	Topics
12/10/2008	euro summit	Agreement on further steps to restore confidence and proper functioning of the financial system; aiming at appropriate and efficient financing conditions for the real economy; concerted action plan to ensure liquidity for financial institutions and enhance cooperation procedures among European countries.
15-16/10/2008	formal EC	Mutual consent to take arrangements to protect the European financial system and depositors; proposal to increase minimum protection for bank deposits to EUR 100,000 to maintain the confidence of depositors in the financial safety net; need for further action to strengthen European and international market rules and supervision.
07/11/2008	informal EC	Confirmation of unity of the EU member states in crisis confrontation; agreement on specific principles and approaches to be adopted at the G20 Summit to initiate reforms of the international financial system; support of IMF; demand for more oversight and regulation of financial industry, more accountability, transparency and new approaches to evaluate risk.
11-12/12/2008	formal EC	Approval of a European Economic Recovery Plan (equivalent to about 1.5 percent of the GDP of the EU27) that provides a common framework for the efforts made by member states and by the EU; ensuring consistency and maximizing effectiveness.
01/03/2009	informal EC	General agreement that Europe can only overcome the current crisis by continuing to act together in a coordinated manner; confidence in the medium and long term outlook of all EU economies; focusing on specific actions on building confidence and promoting financial stability, getting the real economy back on track and working together on global level.
19-20/03/2009	formal EC	Expression of confidence that EU is able to tackle the crisis; pledge of an EU-wide fiscal stimulus of over EUR 400 billion; concerted action and coordination as essential part of Europe's crisis strategy; willingness to speed up agreement on pending legislative proposals on financial sector; coordination of EU position for G20 in London on April 2.
18-19/06/2009	formal EC	Review of EU coordination on the crisis; call for swift disbursement of the next installment of EU balance of payments assistance; call for further progress in regulation of financial markets; endorsement of creation of a European Systemic Risk Board chaired by a ECB member; call for installation of European System of Financial Supervisors; request to ECOFIN and Commission to prepare coordinated position for G20 Summit in September.
17/09/2009	informal EC	Coordination of EU position for G20 Summit.
29-30/10/2009	formal EC	Concern about the deterioration of employment situation; call on ECOFIN to finalize plans for setting up European Systemic Risk Board (macro-prudential supervision) and European Supervisory Authorities (micro-prudential supervision); endorsement of G20 Summit decisions and renewed call for thorough preparation of EU position ahead of G20 meetings.
19/11/2009	informal EC	Expression of great satisfaction that the Lisbon Treaty will enter into force on December 1.
10-11/12/2009	formal EC	Emphasis of the need for coordinated exit strategies and compatibility with the SGP; request for ECOFIN report on exit strategies by June 2010; calls on the EP to quickly adopt the various legislative proposals on financial regulation; calls for new Europe2020 strategy including a review of existing methodology.
11/02/2010	informal EC	As shared responsibility all euro area members must conduct national policies in line with agreed rules; support of all efforts to ensure the ambitious targets of Greece of the 2010 stability program: implement all measures to effectively reduce the budgetary deficit by 4 percent in 2010; declaration of determined and coordinated action to safeguard financial stability.
25-26/03/2010	formal EC	Recognition of Greek efforts to regain full confidence of the markets; reaffirmation of EU member's willingness to safeguard financial stability in the euro area as a whole; mechanism package involve substantial financing of IMF and of a majority of European financing; Euro area members are ready to contribute to coordinated bilateral loans.
07/05/2010	euro summit	Finalizing procedures to implement Greek support package; first disbursement to be made before May 19; assessment of Greek government program; confirmation to accelerate consolidation and sustainability of public finances, strict enforcement of recommendations under the SGP.
17/06/2010	formal EC	Agreement on support package for Greece and on European financial stabilization mechanism and facility; finalization and implementation of Europe2020; collective determination to ensure fiscal sustainability; legislative measures by addressing gaps in regulation and supervision on financial markets; coordination of EU economic policies; agreement on the SGP as well as on budgetary and broader macroeconomic surveillance.

16/09/2010	formal EC	Discussion about new stimulations of the Union's external relations and opportunities of the Lisbon Treaty; need of a more assertive promotion of Europe's interests and values; agreement on concrete measures to more generally enhance the effectiveness of the Union's external policy; presentation of first results of Task Force on economic governance.
28-29/10/2010	formal EC	Call for increased fiscal discipline, broader economic surveillance, deeper coordination; setting up framework for crisis management and stronger institutions with the objective to effectively implement the new agreement by summer 2011; additional agreement on establishment of permanent crisis mechanism to safeguard financial stability of the euro area.
16-17/12/2010	formal EC	Endorsement of the creation of the ESM; agreement on the general features of the mechanism and on a draft decision with the reservations that there has to be a formal approval by all EU member states in accordance with their constitutional requirements to establish it.
04/02/2011	formal EC	Proposals on economic governance shall be agreed on by the end of June to strengthen SGP and to implement new framework; identification of EU-economy-related tasks that should be completed before next Council meeting; readiness to achieve "new quality of economic policy coordination" in euro area to improve competitiveness.
11/03/2011	extra-ordinary EC	Acknowledgment of progress in implementing the ongoing IMF/EU programs in Greece and Ireland; appreciation of Portugal's new package; request to the ministers of finance to finish work on ESM and EFSF until end of March 2012; conclusions until now affect financing capacity (EUR 500 bn), instruments (financial assistance in form of loans) and financial conditions (lower interest rates and maturity); demand to all euro area members to develop action plans for banks that show vulnerability in stress tests; numerical benchmark of 1/20 debt reduction; financial transaction tax shall be explored and developed further.
24-25/03/2011	formal EC	Implementation of European Semester including Europe 2020, fiscal consolidation and structural reforms; package of six legislative proposals to strengthen economic governance; Euro Plus Pact to provide new quality of economic policy coordination; review processes to restore banking sector; setting up ESM (planned to be launched in January 2013).
23-24/06/2011	formal EC	Implementation of European Semester nearly completed; recognition of future ESM and amended EFSF as well as substantial progress made on the legislative proposals on economic governance; Commission's evaluation of member states programs and adjustment programs if period commitments were not fulfilled; preparation of decisions concerning Greece to be taken in July.
21/07/2011	euro summit	Raft of measures to alleviate the Greek debt crisis and to ensure financial stability in the euro area; new financial support program for Greece (EUR 109 bn), voluntary contribution from private sector (EUR 37 bn) and extension of maturities as well as lowering of lending rates (also for Portugal and Ireland); improve effectiveness of EFSF and ESM; finalize legislative package to strengthen SGP plus EU's new macroeconomic surveillance; full disbursement of fifth trance of Greek Loan Facility.
23/10/2011	formal EC	Stressing importance of implementation of Europe 2020 strategy; priorities to be fast-tracked because of significant impact in short to medium term; focusing on growth-enhancing aspects of EU's external policies to maximize contribution to Europe's growth and to attract foreign investments; setting position for G20 Summit.
26/10/2011	informal EC/ euro summit	Preparations of Euro Summit; common resolve to overcome the crisis in spirit of solidarity; main agreements: raise confidence in banking sector; ensure fiscal discipline and accelerate structural reforms for growth and employment; strengthening economic and fiscal coordination and surveillance; measures to improve governance in euro area.
08-09/12/2011	formal EC	Need to adopt measures with most potential to boost growth and jobs in key priority areas; launch of next European Semester; more specific and measurable commitments of Euro Plus Pact member states in particular to advance work as regards employment.
30/01/2012	informal EC	Finalization of Fiscal Compact; ESM ready for signature (legal validity from July 2012); urge to take all necessary steps to implement PSI program in Greece including commitment of all political parties to it; further support of Ireland and Portugal due to achieving quantitative performance criteria and structural benchmark; measures in Italy and Spain to reduce public deficit and to raise growth and employment.
01-02/03/2012	formal EC/ euro summit	Discussion on implementation of EU's economic strategy; endorsement of the five priorities for 2012 set out in the Annual Growth Survey; revision of actions on national levels; signing of Fiscal Compact; setting of priorities for G20 Meeting and UN Rio+20 Conference.
10/05/2010	ECB	Purchase of government bonds
06/12/2010	ECB	Purchase of government bonds
10/02/2011	ECB	Purchase of government bonds
04/08/2011	ECB	Purchase of government bonds
22/08/2011	ECB	Purchase of government bonds
05/01/2012	ECB	Purchase of government bonds
08/10/2008	ECB	Decrease of key interest rates
06/11/2008	ECB	Decrease of key interest rates
04/12/2008	ECB	Decrease of key interest rates
15/11/2009	ECB	Decrease of key interest rates
05/03/2009	ECB	Decrease of key interest rates
02/04/2009	ECB	Decrease of key interest rates
07/05/2009	ECB	Decrease of key interest rates
07/04/2011	ECB	Decrease of key interest rates
07/07/2011	ECB	Decrease of key interest rates
03/11/2011	ECB	Decrease of key interest rates
08/12/2011	ECB	Decrease of key interest rates
22/12/2011	ECB	First 36-month longer-term refinancing operation
01/03/2012	ECB	Second 36-month longer-term refinancing operation

Source: General Secretariat of the Council (n.d.), European Commission (n.d.), European Central Bank (n.d.)
Notes: EC = European Council, ECB = European Central Bank.

Table D.2: Test results for general stock prices

		1/9/2008 - 30/4/2012 (26 events)				1/1/2010 - 30/4/2012 (16 events)			
		2 days	5 days	10 days	15 days	2 days	5 days	10 days	15 days
France	*short-term*	61.5				68.8*			
(CAC 40)	*direction*	69.2**	42.3	53.9	57.7	68.8*	43.8	62.5	62.5
	smoothing	53.9	57.7	46.2	46.2	62.5	62.5	50.0	56.3
	reversal	63.6	46.2	58.3	58.3	50	42.9	83.3	62.5
	volatility	42.3	57.7	53.9	50.0	31.3	56.3	43.8	37.5
	ms-test	0.072	0.046	-0.010	-0.011	0.095*	0.027	-0.022	0.010
	t-stat.	(1.474)	(1.198)	(-0.388)	(-0.528)	(1.769)	(0.823)	(-0.764)	(0.519)
Germany	*short-term*	50.0				50.0			
(DAX)	*direction*	38.5	61.5	80.8**	73.1*	31.3	68.8	87.5**	75.0
	smoothing	42.3	50.0	57.7	65.4*	25.0	50.0	50.0	56.3
	reversal	16.7	57.1	80.0*	69.2	16.7	57.1	100.0**	66.7
	volatility	46.2	53.9	50.0	46.2	62.5	56.3	50.0	50.0
	ms-test	-0.105	0.092	0.024	0.014	-0.208	0.052	-0.013	-0.007
	t-stat.	(-0.656)	(1.084)	(0.523)	(0.445)	(-1.025)	(0.552)	(-0.209)	(-0.150)
Greece	*short-term*	38.5				37.5			
(Athex	*direction*	42.3	42.3	42.3	38.5	43.8	43.8	43.8	37.5
General Share	*smoothing*	38.5	50.0	50.0	46.2	37.5	43.8	43.8	37.5
Price Index)	*reversal*	36.4	43.8	40.0	33.3	42.9	44.4	44.4	36.4
	volatility	34.6	46.2	53.9	61.5	25.0	31.3	50.0	62.5
	ms-test	-0.351	-0.205	-0.003	-0.044	-0.233	-0.286	-0.059	-0.108
	t-stat.	(-0.657)	(-0.789)	(-0.022)	(-0.389)	(-0.436)	(-1.437)	(-0.404)	(-0.777)
Ireland	*short-term*	53.8				62.5			
(ISEQ Overall	*direction*	23.1	42.3	42.3	53.9	18.8	50.0	56.3	68.8*
Index)	*smoothing*	46.2	53.9	46.2	53.9	43.8	56.3	56.3	62.5
	reversal	28.6	45.5	50.0	53.9	25.0	57.1	50.0	75.0
	volatility	42.3	50.0	42.3	46.2	43.8	43.8	25.0	25.0
	ms-test	-0.285	0.010	-0.010	0.006	-0.221	0.034	0.007	0.043
	t-stat.	(-0.967)	(0.071)	(-0.111)	(0.084)	(-1.022)	(0.296)	(0.080)	(0.597)
Italy	*short-term*	53.8				56.3			
(FTSE MIB)	*direction*	34.6	34.6	38.5	19.2	37.5	25.0	25.0	18.8
	smoothing	30.8	26.9	38.5	46.2	37.5	18.8	31.3	37.5
	reversal	40.0	30.8	50.0	11.8	50.0	22.2	37.5	12.5
	volatility	46.2	46.2	50.0	42.3	37.5	50.0	56.3	43.8
	ms-test	-0.209	-0.110	-0.006	0.020	-0.067	-0.127	-0.092	-0.050
	t-stat.	(-1.442)	(-1.109)	(-0.094)	(0.431)	(-0.353)	(-1.413)	(-1.600)	(-1.365)
Portugal	*short-term*	61.5				62.5			
(PSI 20)	*direction*	38.5	53.9	46.2	38.5	37.5	43.8	43.8	37.5
	smoothing	53.9	65.4*	53.9	61.5	56.3	68.8*	50.0	62.5
	reversal	28.6	42.9	47.1	50.0	20.0	33.3	50.0	50.0
	volatility	26.9	34.6	50.0	50.0	25.0	25.0	43.8	37.5
	ms-test	-0.189	0.030	0.094	0.078	0.003	0.079	0.136	0.119
	t-stat.	(-0.737)	(0.236)	(1.097)	(1.059)	(0.013)	(0.674)	(1.454)	(1.520)
Spain	*short-term*	61.5				62.5			
(IBEX 35)	*direction*	38.5	38.5	42.3	46.2	31.3	31.3	37.5	43.8
	smoothing	42.3	34.6	69.2**	50.0	37.5	31.3	75.0**	50.0
	reversal	53.9	22.2	33.3	53.3	44.4	14.3	35.7	45.5
	volatility	53.9	53.9	53.9	53.9	43.8	50.0	50.0	50.0
	ms-test	0.067	-0.139	-0.013	0.000	0.101	-0.094	0.069	0.032
	t-stat.	(0.478)	(-1.535)	(-0.189)	(-0.005)	(0.545)	(-1.283)	(1.188)	(0.608)

Notes: ***, ** and * indicate significance at the 99, 95 or 90 percent level, respectively. All sign test results are stated as the percentage share of successes compared to the total number of events. The reversal criterion is based on a smaller number of total events because it requires a negative development during the pre-event phase according to the success criterion defined in Equation 6.4.

Table D.3: Test results for financial stock prices

		1/9/2008 - 30/4/2012 (26 events)				1/1/2010 - 30/4/2012 (16 events)			
		2 days	5 days	10 days	15 days	2 days	5 days	10 days	15 days
Greece *(FTSE/ Athex Banks Index)*	*short-term*	42.3				43.8			
	direction	46.2	34.6	30.8	26.9	43.8	43.8	43.8	43.8
	smoothing	42.3	50.0	46.2	42.3	31.3	37.5	31.3	31.3
	reversal	46.2	27.8	29.4	22.2	33.3	10.0	20.0	20.0
	volatility	38.5	50.0	53.9	53.9	31.3	50.0	56.3	56.3
	ms-test	-0.848	-0.565	-0.097	-0.069	-1.235	-0.950**	-0.350	-0.351
	t-stat.	(-1.075)	(-1.277)	(-0.417)	(-0.331)	(-1.439)	(-2.210)	(-1.383)	(-1.561)
Ireland *(ISEQ Financial Index)*	*short-term*	38.5				37.5			
	direction	38.5	26.9	34.6	30.8	50.0	31.3	37.5	25.0
	smoothing	65.4*	46.2	46.2	57.7	56.3	43.8	31.3	50
	reversal	42.1	26.7	26.7	29.4	54.6	25.0	22.2	18.2
	volatility	38.5	34.6	42.3	46.2	25.0	18.8	31.3	31.3
	ms-test	0.488	0.099	0.008	0.230	-0.538	-0.204	-0.478**	-0.203
	t-stat.	(0.550)	(0.144)	(0.021)	(0.525)	(-0.573)	(-0.461)	(-2.459)	(-0.796)
Spain *(Barcelona Stock Exchange Banking Index)*	*short-term*	57.7				56.3			
	direction	46.2	50.0	57.7	50.0	43.8	43.8	50.0	43.8
	smoothing	46.2	38.5	38.5	46.2	43.8	43.8	43.8	43.8
	reversal	42.9	45.5	53.9	41.7	40.0	33.3	40.0	37.5
	volatility	38.5	42.3	57.7	46.2	43.8	37.5	56.3	43.8
	ms-test	0.078	-0.320	-0.091	0.024	0.405	-0.092	0.094	0.055
	t-stat.	(0.182)	(-1.466)	(-0.604)	(0.227)	(0.693)	(-0.368)	(0.560)	(0.462)

Notes: See Table D.2.

Table D.4: Test results for government bonds

		1/9/2008 - 30/4/2012 (26 events)				1/1/2010 - 30/4/2012 (16 events)			
		2 days	5 days	10 days	15 days	2 days	5 days	10 days	15 days
France	*short-term*	50.0				37.5			
	direction	42.3	53.8	53.8	53.8	43.8	62.5	62.5	62.5
	smoothing	30.8	30.8	38.5	42.3	37.5	31.3	37.5	56.3
	reversal	12.5	40.0	50.0	40.0	0.0	60.0	60.0	50.0
	volatility	30.8	30.8	34.6	42.3	37.5	31.3	31.3	56.3
	ms-test	0.080***	0.094**	0.091**	0.081**	0.099***	0.078*	0.063	0.038
	t-stat.	(2.760)	(2.351)	(2.304)	(2.102)	(2.847)	(1.822)	(1.292)	(0.821)
Germany	*short-term*	69.2*				75.0*			
	direction	61.5	50.0	53.8	53.8	56.3	43.8	50.0	50.0
	smoothing	61.5	50.0	50.0	53.8	62.5	50.0	56.3	62.5
	reversal	50.0	38.5	57.1	41.7	45.5	40	55.6	37.5
	volatility	42.3	50.0	50.0	53.8	31.3	43.8	43.8	43.8
	ms-test	-0.015	-0.023	-0.018	-0.005	-0.059*	-0.057*	-0.054*	-0.038
	t-stat.	(-0.450)	(-0.898)	(-0.712)	(-0.258)	(-1.894)	(-1.939)	(-1.713)	(-1.604)
Greece	*short-term*	48.0				40.0			
	direction	36.0	36.0	36.0	32.0	40.0	40.0	40.0	33.3
	smoothing	36.0	40.0	36.0	24.0	33.3	46.7	40.0	26.7
	reversal	40.0	36.4	45.5	33.3	50.0	42.9	60.0	33.3
	volatility	36.0	40.0	36.0	24.0	33.3	46.7	40.0	26.7
	ms-test	-0.026	0.211	0.498*	0.690**	-0.105	0.182	0.634	0.906*
	t-stat.	(-0.130)	(0.975)	(1.728)	(2.112)	(-0.329)	(0.516)	(1.348)	(1.705)
Ireland	*short-term*	57.7				56.3			
	direction	53.8	53.8	53.8	53.8	56.3	62.5	56.3	62.5
	smoothing	42.3	46.2	38.5	30.8	37.5	43.8	37.5	31.3
	reversal	77.8*	54.5	50.0	62.5	100.0	66.7	60.0	80.0
	volatility	42.3	46.2	38.5	30.8	37.5	43.8	37.5	31.3
	ms-test	0.048	0.075	0.132	0.186	0.049	0.033	0.107	0.166
	t-stat.	(0.535)	(0.646)	(0.939)	(1.335)	(0.36)	(0.189)	(0.492)	(0.763)
Italy	*short-term*	57.7				50.0			
	direction	42.3	50.0	38.5	46.2	37.5	43.8	37.5	56.3
	smoothing	34.6	34.6	38.5	38.5	31.3	31.3	37.5	56.3
	reversal	25.0	40.0	33.3	53.8	25.0	60.0	42.9	75.0
	volatility	34.6	34.6	38.5	34.6	31.3	31.3	37.5	50.0
	ms-test	0.071*	0.091	0.107*	0.112	0.094	0.087	0.091	0.078
	t-stat.	(1.677)	(1.638)	(1.712)	(1.557)	(1.576)	(1.168)	(1.013)	(0.732)
Portugal	*short-term*	53.8				43.8			
	direction	46.2	46.2	42.3	34.6	50.0	50.0	37.5	37.5
	smoothing	30.8	38.5	38.5	30.8	31.3	43.8	37.5	25
	reversal	60.0	25.0	28.6	14.3	100.0	50.0	33.3	33.3
	volatility	30.8	38.5	38.5	30.8	31.3	43.8	37.5	25.0
	ms-test	0.097	0.136	0.214*	0.291**	0.134	0.144	0.249	0.355**
	t-stat.	(1.025)	(1.442)	(1.735)	(2.531)	(0.897)	(0.992)	(1.286)	(1.983)
Spain	*Short-term*	57.7				56.3			
	direction	53.8	61.5	57.7	53.8	56.3	56.3	62.5	62.5
	smoothing	30.8	42.3	42.3	38.5	31.3	37.5	43.8	43.8
	reversal	55.6	40.0	27.3	27.3	60.0	40.0	42.9	42.9
	volatility	30.8	42.3	42.3	38.5	31.3	37.5	43.8	43.8
	ms-test	0.059	0.077*	0.096*	0.093*	0.078	0.061	0.077	0.061
	t-stat.	(1.405)	(1.661)	(1.893)	(1.703)	(1.325)	(1.092)	(1.138)	(0.804)

Notes: See Table D.2. The sample for Greece ends at February 29, 2012 to avoid any distortions due to the haircut. Events are, therefore, 25 and 15, respectively.

Table D.5: Test results for the euro-dollar exchange rate

		1/9/2008 - 30/4/2012 (26 events)				1/1/2010 - 30/4/2012 (16 events)			
		2 days	5 days	10 days	15 days	2 days	5 days	10 days	15 days
euro-dollar exchange rate	*short-term*	50.0				56.3			
	direction	46.2	50.0	61.5	50.0	50.0	62.5	62.5	56.3
	smoothing	53.8	50.0	65.4*	61.5	56.3	50	68.8*	68.8*
	reversal	50	50.0	61.5	46.2	55.6	71.4	71.4	50.0
	volatility	61.5	53.8	46.2	50.0	68.8*	50	43.8	50.0
	ms-test	0.057	0.007	0.020	0.006	0.106	0.045	0.008	0.004
	t-stat.	(0.431)	(0.124)	(0.461)	(0.192)	(0.849)	(0.838)	(0.176)	(0.14)

Notes: See Table D.2.

Table D.6: ECB bond purchases

		Government Bonds 1/1/2010 - 30/4/2012 (6 events)				Stock Prices 1/1/2010 - 30/4/2012 (6 events)			
		2 days	5 days	10 days	15 days	2 days	5 days	10 days	15 days
Germany	*short-term*	66.7				66.7			
	direction	50.0	33.3	33.3	33.3	50.0	50.0	33.3	66.7
	ms-test	0.044	0.07***	0.034	-0.002	-0.123	-0.042	-0.183*	-0.091
	t-stat.	(0.917)	(3.03)	(1.102)	(-0.048)	(-0.513)	(-0.279)	(-1.651)	(-0.777)
Greece	*short-term*	33.3				16.7			
	direction	50.0	66.7	50.0	0.0	33.3	33.3	33.3	16.7
	ms-test	-0.449	-0.044	0.3	0.676	-1.328	-0.095	-0.339	-0.214
	t-stat.	(-0.587)	(-0.074)	(0.528)	(0.261)	(-1.493)	(-0.535)	(-2.053)	(-0.877)
Italy	*short-term*	50.0				33.3			
	direction	50.0	66.7	66.7	50.0	66.7	66.7	50.0	50.0
	ms-test	-0.1087	-0.168	-0.049	-0.032	0.2	0.337***	0.104*	0.123***
	t-stat.	(-1.061)	(-1.561)	(-0.442)	(-0.264)	(0.796)	(3.555)	(1.654)	(3.286)
Spain	*short-term*	33.3				33.3			
	direction	66.7	66.7	33.3	33.3	66.7	33.3	50.0	33.3
	ms-test	-0.165	-0.19	-0.067	-0.007	-0.250	-0.052	0.048	-0.026
	t-stat.	(-1.163)	(-1.206)	(-0.430)	(-0.039)	(-0.667)	(-0.250)	(0.621)	(-0.514)

		Euro-Dollar Exchange Rate 1/1/2010 - 30/4/2012 (6 events)			
		2 days	5 days	10 days	15 days
	short-term	33.3			
	direction	66.7	38.3	50.0	50.0
	ms-test	-0.103	0.111	0.051	0.025
	t-stat.	(-0.660)	(1.44)	(1.103)	(0.68)

Notes: See Table D.2.

Table D.7: ECB interest rates and liquidity policy

		Government Bonds 1/1/2010 - 30/4/2012 (13 events)				Stock Prices 1/1/2010 - 30/4/2012 (13 events)			
		2 days	5 days	10 days	15 days	2 days	5 days	10 days	15 days
Germany	*short-term*	92.3**				53.8			
	direction	46.2	15.4	23.1	30.8	46.2	61.5	69.2	69.2
	ms-test	0.031	0.046	0.067**	0.044*	0.195	0.108	0.056	0.091*
	t-stat.	(0.416)	(1.049)	(2.178)	(1.761)	(1.291)	(1.232)	(0.808)	(1.7)
Greece	*short-term*	38.5				46.2			
	direction	23.1	38.5	23.1	30.8	53.8	61.5	38.5	38.5
	ms-test	0.806**	1.082**	1.425**	1.433***	0.703	0.135	0.032	0.137
	t-stat.	(2.285)	(2.017)	(2.395)	(2.623)	(1.402)	(0.457)	(0.216)	(0.279)
Italy	*short-term*	46.2				53.8			
	direction	30.8	38.5	38.5	38.5	53.8	30.8	61.5	30.8
	ms-test	0.22**	0.218**	0.244**	0.308**	-0.094	0.049	0.094	0.059
	t-stat.	(2.114)	(2.14)	(2.004)	(2.238)	(-0.376)	(0.302)	(0.84)	(0.617)
Spain	*short-term*	46.2				53.8			
	direction	23.1	38.5	30.8	30.8	30.8	15.4	30.8	38.5
	ms-test	0.223***	0.186***	0.186*	0.239*	-0.451*	-0.204**	-0.122	-0.081
	t-stat.	(2.619)	(2.617)	(1.716)	(1.784)	(-1.777)	(-1.930)	(-1.028)	(-1.019)

		Euro-Dollar Exchange Rate 1/1/2010 - 30/4/2012 (13 events)			
		2 days	5 days	10 days	15 days
	short-term	46.2			
	direction	46.2	46.2	38.5	38.5
	ms-test	-0.311**	0.016	-0.019	0.014
	t-stat.	(-2.370)	(0.253)	(-0.292)	(0.333)

Notes: See Table D.2.

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Eidesstattliche Versicherung

Ich, Herr Marco Zimmermann, versichere an Eides statt, dass die vorliegende Dissertation von mir selbstständig und ohne unzulässige fremde Hilfe unter Beachtung der *Grundsätze zur Sicherung guter wissenschaftlicher Praxis an der Heinrich-Heine-Universität Düsseldorf* erstellt worden ist.

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