Price Formation and Liquidity Provision in Short-Term Fixed Income Markets[1]

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Abstract

This paper examines price and liquidity dynamics in short-term European and Canadian government securities markets. The information content of trades, relative limit orders depth and spreads are examined. Order flow and relative order book imbalances are comparatively informative for European securities listed on the dominant electronic interdealer trading platform in Europe. In Canada, spreads are highly informative. In general, information is usually fully incorporated into prices over a couple of hours. Lastly, we find that prices do not adjust instantaneously to their fundamental value in response to macro news innovations. Rather, there is an induced effect through trades, orders and spreads.

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1. Introduction

Efficient and liquid government securities markets are often viewed as important to a country's economic well-being because they perform a number of key roles. For example, given their virtually default-free nature, government securities are used as benchmarks for the pricing and hedging of other fixed-income securities. In the short-term interest rate sector, liquid government markets allow financial market participants to cost-effectively build positions based on their views of the expected future path of overnight interest rates. Monetary policy makers, concerned about disorderly markets, can determine if future interest rate-setting decisions will surprise financial markets. Individual market participants can examine the differences between their own forecast regarding the direction and magnitude of future rate changes and the overall market's forecast. Only if short-term interest rate markets are efficient, can accurate measures of market expectations be calculated.[3]

Government securities markets, even those outside the U.S. Treasury market, are usually thought to be highly liquid and efficient. This assumption is tested with new trade and quote data. In this paper, we examine how information is incorporated into European and Canadian government bond prices, how prices and liquidity are jointly determined, and the process by which 'news' is incorporated into prices.

It is important to account for the structure and organization of a financial market when investigating how prices and liquidity evolve over time. Albanesi and Rindi (2000) find that liquidity and the process of price discovery improved once the posting of limit-orders became anonymous on the Mercato Telematico dei Titoli de Stato (MTS) platform---the dominant electronic platform for interdealer trading of government securities in Europe. Recently, with the introduction of the euro in 1999, a "liquidity pact" was adopted by

[3] Johnson (2003) describes how simple expectations-based models can be utilized to extract expectations. Usually, securities with maturities less two years are employed in this exercise.

dealers and issuers of securities listed on MTS. Market makers of designated securities must continuously post buy and sell limit-orders within a maximum bid-ask spread, for a minimum quote amount on both sides of the market, for at least 5 hours each day. According to advocates of the liquidity pact, the accord should increases liquidity in government securities markets and thereby reduces the costs to governments of funding their debt.

In Canada, a large proportion of government securities trading take place via interdealer brokers (IDBs). While there are no quoting obligations in Canada, dealers in the market, usually representing financial institutions, commit themselves to trade continuously in the market by posting a bid price and an ask price for each government security. In either geographic region, dealers observe order flow, limit orders and spreads in the market.

In this paper, high-frequency trade and quote data from a number of short-term European and Canadian government securities with maturity less than or equal to 2-years are analysed. Our paper investigates the relationship between price changes, order flow, relative limit order depth and spreads. Green (2004), Brandt and Kavajecz (2004) and Pasquariello and Vega (2004) demonstrate that order flow is informative in fixed-income markets. In addition to order flow, we also examine the role of liquidity supply in price formation process. Since relative liquidity supply provides an indication of how much dealers are willing to buy versus sell, it should convey information. Angel (1994) and Bloomfield, O'Hara and Saar (2003) illustrate how informed traders will use both market and limit orders strategically.

While Chordia, Sarkar and Subrahmanyam (2005) also examine return and liquidity dynamics across U.S. equity and long-dated U.S. Treasury bond markets, very little is known about the price discovery process and liquidity dynamics in government fixed-income markets for securities with maturities less than two years. This is especially true of securities issued outside the U.S. Treasury market.

The existence of informed trading and liquid markets are related. Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) predict that there will be a clustering of liquidity and informed traders. Kim and Verrecchia (1994) argue that, if informed traders possess an informational advantage after an event, liquidity will remain low as long as those informed traders maintain that advantage. The supply of liquidity in markets affects the speed with which information is incorporated into prices. In general, liquidity should be viewed as endogenous. Motivated by questions associated with the relationship between price changes, order flow, relative limit order depth and spreads, we utilize the framework of Hasbrouck (1991a, b) and Chordia, Roll and Subrahmanyam (2000, 2001). A reduced form vector autoregression (VAR), in which each variable depends on the lagged values of the all other variables, is estimated. The persistent impact on prices from shocks to other variables in the system is assumed to arise from asymmetric information.

Our findings indicate that there is a high degree of autocorrelation in each variable which is consistent with lagged adjustment and/or inventory control effects. Results suggest that order flow and order book imbalances can have a permanent impact on prices. Unlike European securities, spreads are particularly informative in the Canadian market. Nevertheless, in terms of the time it takes markets to adjust, Canadian securities are similar to those of European securities.

We also examine the price and liquidity dynamics in times of macroeconomic news releases. These announcements are public information which should affect prices immediately before anyone can trade on them. There may be a role for trades and orders in the price discovery process if participants differ about how to interpret macroeconomic news, or alternatively, if some traders are better able to process public information. In this environment, private information will dissipate once it is first reflected in trades and orders, and then subsequently in prices.

Fleming and Remolona (1999) and Balduzzi, Elton, and Green (2001) find that U.S. Treasury markets react to public macroeconomic information with a sharp reduction in liquidity combined with rapid price changes as information is absorbed, and then a

subsequent surge in trading activity as participants trade on their differing views regarding the interpretation of the new information. Green (2004) looks at the role of trading around macroeconomics news announcements and finds that information asymmetry rises in the wake of an important macroeconomic news announcement. Evans and Lyons (2004) find that news-induced trades last for days, and have persistent effects on foreign exchange rates. In this paper, we examine the effects of news innovations and the reaction of order flow, order book imbalances and spreads. Like Evans and Lyons, we also find that news generates informed order flow but uninformative order book imbalance and spreads effects.

In the next section of the paper, Section 2, we describe in more detail the institutional structure of the MTS electronic trading platform, the Canadian interdealer brokered market, and the data employed in our study. In Section 3, we discuss the empirical model estimated. Our results and their significance are explained in Section 4. In Section 5, we conclude.

2. Institutional Structure and Data

In Europe, the trading platform in fixed-income securities is the MTS, which is the dominant electronic trading platform.[4] Interdealer trading accounts for more that half of all trading volumes.[5] There are generally two types of market participants on MTS: primary dealers and dealers. Primary dealers must fulfill a number of requirements under a "liquidity pact" with issuers. These primary dealers must continuously post buy and sell limit-orders within a maximum bid-ask spread, for a minimum quote amount, and for a given period of time each day. In return for meeting these obligations, the primary dealers have access to primary auctions and enjoy privileged relations with the issuing

[4] MTS was created in 1988 by the Italian Treasury and the Bank of Italy with the objective of increasing competition and efficiency in the market for government debt. MTS became a private company in 1997. EuroMTS was introduced in 1999.
[5] The Bond Market Association (TBMA, 2005).

authorities. They also receive private information about the trading activity on MTS, market and economic conditions, and policy information from issuers.

European government bonds can be listed on a domestic MTS platform (such as MTS France) and/or the EuroMTS electronic trading system. Those fixed income securities that satisfy a number of listing requirements, such as exceeding a required principal amount outstanding and certification that a number of dealers that will act as markets marker in that security, can be listed on EuroMTS. All government marketable securities, in addition to benchmarks, are listed on their respective domestic MTS platform (subject to a given outstanding principal amount). Cheung, de Jong and Rindi (2005) find that trading costs are similar on both platforms. In our study, we examine trading and quoting information for Treasury bills from the domestic market platform since almost all trading of short-dated securities occurs on the domestic platform.

CanPx is a data service that consolidates and disseminates to interested subscribers anonymous trade and quote data submitted by Canada's fixed-income interdealer brokers (IDBs). Based on dealer statistics reported to the Investment Dealers Association (IDA), the Canadian interdealer debt market represented approximately 46 per cent of the total secondary Government of Canada bond market trading volume during 2002, of which IDB trading accounted for 86 per cent (up from 50 per cent in 1991 and 75 per cent in 1997). The CanPx data set is relatively complete, in that it receives information from all of the Canadian IDBs. Dealers leave firm quotes with the brokers, along with a minimum size that they are willing to trade. The best quotes across all the participating dealers are posted. Unlike MTS, dealer behaviour is not governed by rules that limit bid/ask spreads.

Data

This paper uses quote and transaction data from the MTS trading platform and CanPX. The MTS dataset includes the updates of the best quote, transaction prices and signed quantities traded along with time stamps corresponding to the transactions entering the market. Information about depth is available up to, and including, the third best ask and

bid prices. Our analysis below focuses on Treasury bills listed on the four largest MTS platforms: MTS Italy, MTS Germany, MTS France and MTS Belgium. We analyse short-term government bill data for securities with a maturity from 6 months to 2 years. The MTS data set spans the period from 1 April, 2003 to 31 December 2004. The MTS market opens from 8:15 to 17:30 (Central European Time, CET)[6]. We divide the trading day into 30-minute intervals from 8:00 (CET) onwards. The bonds analysed in our study include: the 6-month Italian Treasury Certificate (BOT), the 6-month French Treasury Bill (FTB), the 6-month German Treasury Certificates (GTC), the 1-year Belgian Treasury Certificate, the 1-year Italian Treasury Certificates (BOT), the 1-year French Treasury Bills (FTB), and the 2-year German Treasury Bond (Schätze).

Data from the Canadian bond market comes from CanPx. We focus on the 2-year Canadian bond.[7] The CanPx dataset spans from 1st October 2003 to 31st October 2004. We divide the trading day into 30-minute intervals from 8:00 (Eastern Daylight Time, EDT) onwards. The following trade and quote information relating to a particular security is available on the CanPX screen: the price and/or yield of the best bid and offer; the total amount offered and bid at each of the best inside quotes (across all of the IDB screens); the time at which the best bid and offer were last updated; whether a buyer-initiated or seller-initiated trade is currently being conducted; and, when a trade is completed, the trade outcome and the name of the IDB where the trade took place.

One of the reasons we examine short-term instruments is because little is known about the price and trade dynamics associated with these securities. The fixed-income market microstructure literature has usually focused on bonds with more than 2 years to maturity. We explore how private information, order flow, and relative liquidity supply, order book imbalance (defined below), affect the short-end of the yield curve.

[6] There is a pre-trade session in the MTS market from 7:45 to 8:15 (CET). During this time, dealers can post limit orders but they are not allowed to trade on these orders.
[7] We do not use the Canadian 6-month and 1-year bill because the quote and transaction frequency is very low on the CanPx system.

Economic Announcements

All of the macroeconomic news announcements we consider occur at, or after, 8:30 a.m. EDT or CET. The announcement data, including the survey expectation of the announcements, are disseminated by Bloomberg. We use real-time data on the expectations and announced macro variables. The European sample includes EU-wide, Belgium, Italy, France, Germany and US scheduled news. The Canadian sample includes Canada and US scheduled news. Both the European and the Canadian news items are listed in Table 6. For each announcement we construct the standardized news, $\eta_{i,t}$, on half-hour interval *t* as,

$$\eta_{i,t} = \frac{N_{i,t} - E_{i,t}}{\hat{\sigma}_i} \qquad (1)$$

where $N_{i,t}$ is the value announced of announcement *i*, $E_{i,t}$ is the median of survey expectation of announcement *i*, and $\hat{\sigma}_i$ is the sample standard deviation of $N_{i,t} - E$. We set $\eta_{i,t} = 0$ on half-hour intervals on days without macroeconomic announcement.

Variables and Descriptive Statistics

We construct the following variables to examine price, information arrival and liquidity dynamics: the 30-minute price change, Δp_t, order flow, $orderflow_t$, order book imbalance, imb_t, and best bid-ask spread, $spread_t$. The change in the best mid-quote is defined as

$$\Delta midquote_t = (mid\ quote_t - mid\ quote_{t-1}) * 1000$$

where $mid\ quote_t$ is the average of the best ask quote and the best bid quote at the beginning of each period *t.* Order book imbalance is defined as

$$imb_t = \frac{(depth\ at\ best\ bid\ price_t * best\ bid\ price_t - depth\ at\ the\ best\ ask\ price_t * best\ ask\ price_t)}{100}$$

in which *depth* is measured in million. It captures the relative supply of liquidity on the two sides of the market. Order flow of the bond, $orderflow_t$, is the defined as the

aggregate volume of buyer-initiated orders minus that seller-initiated order during the hour interval. As shown in previous studies (for example, Green (2004), Brandt and Kavajecz (2004) and Pasquello and Vega (2006) in fixed-income markets, order flow captures the arrival of information. The best bid ask spread is defined as the difference between the best ask price and the best bid price,

$$spread_t = (best\ ask\ \ price - best\ bid\ \ price) * 1000 .$$

Table 1 presents the descriptive statistics for the variables we model. European short-term bills have lower serial correlation in change in mid-quote and higher serial correlation in order book imbalance than Canadian 2-year bond. This may arise from the requirement that dealers in the MTS market have to provide quote for minimum quantity for both sides of market for 5 hours per trading day. So dealers adjust their quote relative quickly. From the correlation matrix, order flow is positively correlated with changes in the mid-quote over all securities.

Adjustment of Time-Series Data

As we are using intra-day data of 30-minute interval, we deseasonalize the endogenous variables using the method proposed by Gallant, Rossi and Tauchen (1992). The first step is to regress each variable on a series of adjustment variables as follows:

$$x = d'\lambda + u \qquad (2)$$

The adjustment variables we use are

1. 17 half-hourly dummies, one for each of the hours between 9:00 (GMT) and 5:30 (GMT).
2. 4 daily dummies, one for each from Monday to Thursday.
3. 11 monthly dummies, one for each from February to December

To remove the heteroscedasticity in our variables, the residuals are used in the regression

$$\log(u^2) = d'\theta + v \qquad (3)$$

The adjusted or deseasonalized variables are then calculated as follows

$$x_{adj} = \bar{x} + \hat{\delta}_x \frac{\hat{u}}{\exp(d'\theta/2)}, \qquad (5)$$

where $\bar{x}$ is the unadjusted sample mean of the variables and $\hat{\delta}_x$ is the unadjusted sample standard deviation. The adjusted series have the same sample mean and variance as the unadjusted series, but the effect of seasonality on the mean and variance is removed.

Table 2 shows the regressions coefficients of Equation (2). For European securities, spread is highest at the beginning of the day. It drops as the trading day proceeds and then rises slightly again before the closing of the market. The result is consistent with the notion that information asymmetry is highest at the beginning of the day. Dealers want to protect themselves against overnight positions before the market closes so they set a higher spread during these times. Spread is also in general higher on Friday. The findings contrast with that of Canadian 2-year bond: spread is not statistically different from the opening half-hour of the market, except for one half-hour interval in the afternoon.

3. Methodology: Econometric Specification

Since market orders, limit-orders and spreads are interrelated; the impact of an innovation in one variable on prices cannot be determined by regressing prices on current and lagged terms. In particular, the execution of a market order will directly affect the depth of limit orders on that one side of the market. Market orders will also affect the future placement and cancellation of limit-orders. In reverse, market orders may only be executed if a certain amount of depth is available in the market. Complicating things further, even after allowing for causality in both directions between order flow and order book imbalances, this relationship will depend on the size of the bid-ask spreads in the market at the time of the market order. In order to determine the implied impact of a market order, or a change in the relative depth of the limit order book, it is necessary to capture the overall dynamic relationship between all variables.

In the paper, we use a vector autoregression (VAR) model to capture the intertemporal associations between price, order flow, order book imbalance and spread. Hasbrouck (1991a, 1991b) proposed using two statistics derived from the VAR specification to determine the effects of order flow on prices: impulse response functions summarize the permanent impact of a variable on prices. Examining impulse response functions, besides the estimated coefficients of a VAR, provide additional insights about the behaviour of prices. Impulse response functions represent the expected future values of a system of equations conditional on an initial shock. By looking the impulse response function of price, information and liquidity measures, we could examine the intertemporal dynamics of these variables through time in more detail. The second measure we use is variance decompositions, which measure the relative importance of each variable in explaining the variability in the endogenous variables. We examine the long-run response of an innovation in a variable explain the error variance of mid-quote change. The variance of the expected value of all future prices changes can be thought of as the variance of the random walk component implicit in all asset prices. By examining the long-run response of price, information and liquidity variables to innovations in the system, variance decomposition allows us to isolate the long-run impact these variables from transitory effect. These two statistics are employed in our analysis to determine the impact of innovation in price, information and liquidity measures on the market quality of each government bond market.

We first examine the dynamics of price, order flow and liquidity measures on days without news announcement by estimating the following VAR system,

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_P y_{t-P} + v_t, \qquad (1)$$

where y_t is defined as

$$y_t = [orderflow_t, imb_t, spread_t, \Delta p_t]'$$

and the A_p's are $(p \times p)$ coefficient matrices of the endogenous variables, y_t. The disturbance, v_t is a column vector with mean zero, $E(v_t) = 0$ and serially uncorrelated disturbances, and covariance matrix $E[v_t v_t'] = \Omega$. The parameters A_p and Ω are unknown and have to be estimated before the necessary impulse response and variance

decomposition statistics can be calculated. Estimates of these parameters can be obtained from least squares. See Hamilton (1994) and Judge et al. (1982) for a discussion of these methods. We choose the order of Equation (1) on the basis of the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC). We choose the minimum lag length from the two criteria.

We next examine how the price, order flow and liquidity measures respond to news announcements. We estimate the following system:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_P y_{t-P} + B\eta_t + v_t,$$

where η_t is the $(n \times 1)$ vector of standardized news variables from Equation (1), where n denotes the number of macro economic news announcement.. The $(p \times n)$ coefficient matrix of the news variables, is represented by B Thus the effect of announcements on the dynamics of the endogenous variables is given by the B coefficients. Our model enables us to examine on intraday basis how long the effects of news announcement persists on price, order flow and liquidity measures.

4. Empirical Results

VAR Estimation Results on Days without Macro News Announcements

The VAR specification described in the previous section is estimated for each of the eight securities in our sample. It consists of four equations that model the interaction between the change in mid-quote, spreads, order book imbalances, and order flow. The coefficient estimates are reported in Table 3. The system of equations is estimated with one or two lags. For the Italian 6-month, the Italian 12-month, and the German 2-year bills only one lag was necessary. Table 4 shows the value of the objective function at various lags for each VAR.

Estimation results are quite similar across securities, and can be summarized as follows. There is evidence of positive and significant order flow, order book imbalance, and

spread autocorrelation. The coefficient of the first lag for these three variables is in general positively significant (at 10% significance level or lower) for all securities. The result associated with order flow suggests that that there exists momentum in buying and selling. Autocorrelation in spreads and order book imbalances can arise for a couple of reasons: (1) uncertainty of the security value persists in the market; or (2) a constraint exists on the maximum spread imposed by MTS market makers. The change in prices is significantly negatively autocorrelated (at 10% significance level or lower) in the French 6-month bill, the Italian 6-month bill, the German 6-month bill and the Canadian 2-year bond. These results suggest the existence of inventory control and lagged adjustment effects in these markets. Turning to the cross-effects of the endogenous variables in the price equations, lag order flow has a significant impact on price dynamics in three markets: the Italian 6-month bill, the French 1-year bill and the Canadian 2-year bond while lag order book imbalance has a positive significant (at 10% level or lower) impact on the pricing of bonds expect in the German 6-month bill, the Belgium 1-year bill and the Canada 2-year bond. These results suggest that order flow and the relative liquidity supply set by dealers may convey information about the pricing of securities in the fixed income markets.

One of the key questions that can be addressed with a VAR is how useful are some variables in forecasting other variables. Table 4 also shows the results of pair-wise Granger-causality tests between each of the endogenous variables. One variable is said to Granger-cause another variable if the information in past and present helps to improve the forecasts of the variable. We test the null hypothesis that variable *x1* does not Granger-cause variable *x2* by testing whether the lag coefficients of *x1* are jointly zero in the equation with *x2* as dependent variable.

For the French 6-month bond, Wald test statistics indicate that there is two-way causality between order book imbalances and price changes. For the Italian 6-month security, both order flow and order book imbalances Granger-cause price change. There is no evidence of causality in the opposite direction. In the German 6-month market, spreads, order book imbalance and order flow do not Granger cause price. Although there is two-way

causality between order flow and order book imbalances, and order book imbalances and spreads. The results of the Belgian 12-month bill are similar to the German 6-month bill: order flow, order book imbalance and spread variables do not Granger-cause price. For the Italian 12-month security, spreads and order book imbalances Granger-cause price changes in the VAR, though there is no evidence the other way around. For the 12-month French market, order flow and order book imbalance Granger-cause price. Again there is no evidence of causality in the other direction. For the German 2-year bond, order book imbalance Granger-cause price.

Lastly, for the Canadian 2-year bond, there is evidence of two-way causality between price and spreads, and order flow is shown to Granger-causes prices. Overall, order book imbalances and order flow forecast price changes except in the German 6-month bill and the Belgian 1-year bill markets. Two-way causality exists between prices and all other variables in the French 6-month bill. Since there is in general a lack of uniformity across securities, we include all four variables in the VAR in all markets.

We now examine the dynamics associated with innovations in prices, order flow, order book imbalances and spreads. For each security market, impulse response functions are calculated to trace out the effect of a one-time shock to order flow, order book imbalance, and spread innovations. Because the innovations are correlated, we orthogonalize the impulse using the inverse of the Cholesky decomposition. We present the results of the following ordering: order flow, order book imbalance, spread and price change.[8] The ordering was chosen for two reasons. First, it is consistent with the theoretical literature suggesting that trades are informative in the price formation process. Therefore order flow is placed first. Second, pair-wise Granger-causality tests provide evidence that order book imbalances forecast price changes. Accordingly, order book imbalance is placed second, after order flow, in the VAR ordering.

[8] In general, the chosen VAR ordering can influence the results. Our results are very similar across orderings.

Figure 1 show the cumulative effect on the change in prices from three types of shocks: a one-standard deviation shock to order flow, a one-standard deviation shock to order book imbalances, and a one-standard deviation shock to spreads. Two standards errors bounds of each impulse response function are also shown the graphs. The long-term cumulative implied price change that occurs subsequent to an innovation in each variable may be interpreted as the informational content of that variable. An order flow shock has a permanent and positive impact on the prices of all European securities and Canadian 2-year bond. This finding is consistent with previous findings in the fixed-income microstructure literature suggesting that order flow is informative and has a permanent impact in the price discovery process.

Except for the Belgium 1-year bill, order book imbalances have an initial negative impact on prices. The effect eventually dies out with prices reverting back to the original level (or higher than their original level in the case of French 1-year bill). The initial drop in price is inconsistent with our usual intuition that larger depth on the buy (bid) side of the market should act as a support level pushing prices upward. One explanation for the initial drop in price could be due to the feedback effect of order flow. A rise in depth on the buy side of the book reduces the marginal cost of selling a security. Dealers attempting to manage their excess inventories are more inclined to immediately execute market sell orders rather than use limit orders. The execution of sell may in turn convey negative information to other dealers about the value of the security which may then reduce prices. Only once dealers determine that the sell market orders are not informative does price revert to its initial long-run level.

The innovation in spreads generally has no impact on prices amongst the European securities except in the Italian 1-year bill market. Spreads have a significantly positive impact on the Italian 1-year bill. For the rest of the securities, the impact of spreads is not statistically different from zero, 5 hours after the initial impact. In contrast, Canadian 2-year bond spread innovations have a significant impact on price dynamics. An increase in spreads results in a permanent reduction in prices. From an informational perspective, large spreads in the market may convince dealers that informed traders may exist in the

market. If liquidity decreases as a result, price may fall subsequently. Spreads, much like order flow, seems to be informative to dealers in the Canadian market.

Next, we briefly discuss the interactions between order flow, order book imbalances and spreads. The impulse response function (not reported here) shows that both order book imbalances and spreads are positively related own innovations. Further, the response of an order book imbalance innovation on order flow is significantly negative in the Italian 6-month bill, the Italian 12-month bill and the German 2-year bond. A negative change in order book imbalances means that the ask depth deepens at the best ask price. The result suggests that dealers supply additional liquidity on the ask side upon observing more buy market orders (with positive order flow) entering the market.

The response of order book imbalance to shock in order flow is quite different in the German 6-month market. It is significantly positive. This implies that dealers deepens the bid depth, or withdraw liquidity from the ask depth, upon observing positive order flow. For Belgium 1-year bill, the French 1-year bill and the Canadian 2-year bond, order book imbalance does not respond to innovations in order flow. Turning to spreads, we find that they do not react to innovations in order flow except for the Italian 6-month bill market. The spread of Italian 6-month bill, the French 12-month bill and the German 2-year bond react positively to innovation in order book imbalance. Spreads do not react to innovations in order book imbalance in the rest of the securities.

To further determine which variables are informative in the price discovery process, we also examine the variance decomposition of price changes. Table 5 shows the decomposition of the 10-period ahead forecast variance of prices in terms of each component variable in the system. We examine this particular forecast so as to isolate any transient effects, focusing only on the long-run, or permanent, explanatory power of each variable in the VAR system. If a variable explains only short-run transient variations in exchange rate changes, it will not perform well in the variance decompositions. Since the variance decomposition is based on the Cholesky identification, it is affected by the ordering of the variables. Table 5 displays the upper- and lower-bound estimates of the

variance decomposition for each endogenous variable from all possible ordering combinations of order flow, order book imbalance, and spreads. The second column contains the forecast error of the variable at the given forecast horizon. The source of this forecast error is the variation in the current and future values of the innovations to each endogenous variable in the VAR. The remaining columns give the percentage of the forecast variance due to each innovation, with each row adding up to 100.

The contribution of order flow, order book imbalances and spreads in explaining the error variance in price change differs across countries. Order flow's explanatory power on error variance of price change is close to 2 % for the Italian 6-month and 1-year bill, the Belgium one-year bill and the Canadian 2-year bond. But it has less than 1% of explanatory power in the German 6-month bill and 2-year bond markets. This may be due to the fact that, as described in Cheung, de Jong and Rindi (2005), trading of German fixed-income securities is concentrated in the futures market and trading on futures is more liquid in the EUREX market. As a result, price discovery occurs in the futures market and the trading of the spot carries less information.

Turning to order book imbalance, it has the highest explanatory power in the French 6-month bill (above 7%) and the French 1-year bill (around 4%) markets. It also has lowest explanatory power on error variance of price in the Canadian market. This could be due to the fact that the Canadian market is a voice-brokered system and there are no constraints imposed on spreads or the minimum quantity supplied to the market. As a result, dealers can adjust both spreads and relative liquidity supplies in times of uncertainty. Thus relative liquidity supply—order book imbalance—has less weight in explaining price dynamics.

For spreads, the results suggest a very small role for spreads in the long-run price-discovery process in European securities. Since minimum spreads are restricted in Europe through the liquidity pact, there information content of spread on price is lower. The variation in spreads may be exclusively related to manage inventories. Impulse response functions of innovation of spread on price confirm the finding as there is no permanent

impact of a spread shock on prices. For the Canadian 2-year bond, the results are significantly different. Spreads explain between 22 and 23% of the long-term variability in prices. The result suggests that spreads in the Canadian bond market are related to innovations in fundamental information.

Impulse Response Functions and News Innovations

In this section, we characterize the behaviour of prices, order flows, order book imbalances and spreads subsequent to news releases. Specifically, we focus on analysis on how news affects each of the variables in our VAR system beyond the announcement time. We attempt to determine if news induces changes in order flow, order book imbalances, spreads, which then affect prices later through time. While macroeconomic news announcements will affects prices directly before anyone can trade on it, after the announcement is made, private information may still exist if participants differ on how to interpret the macroeconomic news. Green (2004) finds that information asymmetry rises in the wake of an important macroeconomic news announcement. Over time, private information in the market will dissipate once it is reflected in trades and order flow, and then subsequently in prices. Evans and Lyons (2004) find that there is evidence of an indirect channel between news and prices through order flow in the FX market.

Table 6 reports the estimated coefficients, B, and their significance, of news innovation on each endogenous variable in the VAR in Equation (2). These coefficients determine the average effect of news shocks on innovations in the VAR. U.S. Non-farm Productivity and the German IFO index survey of business climate have the largest significant impact on European security prices. U.S. Non-farm Productivity has a significantly positive impact on the price change of all European securities except the Italian 6-month bill and the German 6-month bill. A positive one standard deviation shock to Non-farm Productivity leads to price change of more than 3 cents on Italian 1-year bill and German 2-year bond. The German IFO index survey of business climate has a significantly negative impact on the price change of all European securities except the Italian 6-month bill and the German 6-month bill. A positive shock of one standard

deviation to German IFO Index Survey of Business Climate leads to more than 2 cents decline on Italian 1-year bill and German 2-year bond.

Order book imbalances and spreads are affected by a wide range of news innovations. The French Consumer Confidence Indicator, French Non-farm Payrolls, French PPI, the CPI and PPI of Italy, Germany and US are among the most important macroeconomic news variables affecting order book imbalances and spreads. As in the case of price changes, there is a significant cross-country news innovations impact on each of the other variables in the VAR system. For example, an innovation in the French Consumer Confidence Indicator has a significantly negative impact on the order book imbalances of the Italian 1-year bond. The magnitude of the impact is second only to the French 6-month bill. Similarly, the innovations in French Non farm Payrolls and PPI have the greatest impact on the order book imbalances of the Belgium 1-year bill and the spread of the German 2-year bond.

In terms of the Canadian 2-year sector, out of all the macroeconomic news events that were thought to have an impact on government fixed income markets, only a few had a statistically significant contemporaneous impact on prices. The price dynamics of the Canadian 2-year bond is not significantly affected by any news innovations. Canadian industrial production prices (PPI) and U.S. Non-farm Employment Productivity are shown to have positive and statistically significant impact on order flow. U.S. Retail Sales and Housing Starts have a statistically significant impact on Canadian spreads.

To determine if there is a persistent impact of news on the endogenous variables in our system, we present the results of several macroeconomic news innovations that have been shown to have a contemporaneous effect. U.S. Non-farm Productivity French PPI, German IFO Index of Business Climate, and Italian CPI have a statistically significant impact on at least one variable in one endogenous variable across each European security. Both U.S. Non-farm Productivity and Canadian Industrial Production Prices both have an impact on the price of the Canadian 2-year on-the-run bond. Figure 2 summarize the

dynamics of prices, order flow, order book imbalances and spreads following the arrival of each news events through an examination of impulse response functions.

In a number of cases there is a delayed order flow, order book imbalance and spread response after the news event. Prices do not converge to long-run value instantaneously. In the first figure the reaction to a one-standard deviation innovation in French PPI on the accumulated prices change, accumulated order flow, order book imbalances, and spreads in each security market is plotted. Note that price changes and order flow are illustrated in cumulative amounts since they are flow variables in the VAR system. Judging from the top-right-hand-side plot, cumulative order flow is increasing even after 6 intervals, or 3 hours. In the first two intervals prices are also adjusting, partly directly through a lagged adjustment in own prices, but also indirectly though order flow. Spreads and imbalances (lower plots in Figure 2) adjust over a longer period of time. The German 2-year bond usually has the largest temporary adjustment in spreads and order book imbalances to a news innovation.

There is a similar reaction to news innovations in the Canadian 2-year bond market. Prices do not adjust instantaneously to long-run value in response to innovation in news, but adjust over the next one to two hours. There is also evidence that there is induced order flow which indirectly affects prices. Much like the reaction of European securities to news, both order book imbalances and spreads adjust over a period of 3-hours. Since prices have adjusted in interim, these dynamics are probably associated with inventory control affects.

5. Summary and Conclusion

Liquid and efficient government securities markets are important to a country's overall economic well-being. They are necessary to ensure that savings and investment decisions are made optimally. In this paper, we examined the dynamics of price, order flow, order book imbalance and spread on short-term European and Canadian government securities.

We also analysed the relationship between price and liquidity dynamics on days with macroeconomic news announcements. On non-announcement days, consistent with the rest of the literature, order flow has a permanent and positive impact on price. A shock in order book imbalance leads to an initial drop in price but then price reverts back to the long-run level. A shock to spreads does not have a significant long-run impact except in the Canadian markets.

One important feature of government debt markets is the extent to which they are driven by public news, and, in particular, macroeconomic news. The information in scheduled macroeconomic news releases is scrutinized by the market, whose participants seek to determine the future cost of capital. One way in which markets process information is by observing order flow, order book imbalances and spreads. We found that liquidity measures have delayed response to news innovations. It may takes some time before news is fully reflected in prices. Without a larger sample of securities, and additional cross-sectional information about each securities market, we cannot make additional comments about the contribution of market structures to price discovery and liquidity dynamics, or more importantly whether a liquidity pact is needed in the Canadian government securities market.

Overall, our results suggest that, while there are some differences in dynamics, Canadian and European short-term fixed-income market are relatively liquid; they reflect fundamental information in a timely fashion; and they react to news in a manner consistent with evidence from other financial markets.

In future research we will build on results of this paper and explore how prices and relative liquidity supplies are jointly determined across on-the-run and off-the-run securities markets. Since dealers in fixed-income market usually manage a portfolio of securities within a given maturity sector, if securities are similar, a dealer can have a long position in one security and an offsetting short position in another and bear little inventory risk. Primary dealers of both on- and off-the-run securities can manage risk in their portfolio by adjusting prices and liquidity supplies of the two securities jointly. We

will also seek to determine if private information learned about one security is used in the pricing decisions of other similar securities. Inventory control effects may link on- and off-the-run securities.

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Tables and Figures

Table 1: Summary Statistics

Summary statistics for French 6-month bill, Italian 6-month bill, German 6-month bill, Belgium 1-year bill, French 1-year bill, Italy 1-year bill, German 2-year bond and Canadian 2-year bond. The mid-quote change, Δp_t, is the 30-minute change in mid-quote times 1000. Order book imbalance is defined as

$$imb_t = \frac{(depth\ at\ best\ bid\ price_t * best\ bid\ price_t - depth\ at\ the\ best\ ask\ price_t * best\ ask\ price_t)}{100}$$

in which $depth$ is measured in million. Order flow of the bond, $orderflow_t$, is the defined as the aggregate volume of buyer-initiated orders minus that seller-initiated order during the hour interval. The best bid ask spread is defined as the difference between the best ask price and the best bid price.

	mean	std	r_1	r_2	r_3	Δp_t	$orderflow_t$	imb_t	$spread_t$
France 6-month bill									
Δp_t	0.02	1.48	-0.09	0.01	-0.01	1.00	0.10	-0.13	0.00
$orderflow_t$	0.00	5.58	0.02	0.01	0.02		1.00	-0.02	-0.02
imb_t	-0.40	15.61	0.45	0.31	0.25			1.00	0.03
$spread_t$	0.73	0.34	0.75	0.64	0.59				1.00
Italy 6-month bill									
Δp_t	0.07	6.75	-0.02	0.00	0.00	1.00	0.03	-0.01	0.84
$orderflow_t$	-0.10	9.72	0.06	0.02	0.01		1.00	-0.03	-0.01
imb_t	-1.10	10.60	0.51	0.38	0.31			1.00	0.03
$spread_t$	0.58	1.46	0.18	0.15	0.14				1.00
Germany 6month bill									
Δp_t	0.19	14.60	0.00	0.00	0.00	1.00	0.01	0.00	-0.01
$orderflow_t$	0.13	9.85	0.04	0.01	-0.01		1.00	-0.05	0.00
imb_t	-0.98	14.10	0.60	0.46	0.39			1.00	0.06
$spread_t$	0.80	0.31	0.76	0.66	0.59				1.00
Belgium 1-year bill									
Δp_t	0.01	4.78	-0.02	0.04	0.00	1.00	0.15	-0.04	-0.01
$orderflow_t$	-0.06	6.98	0.07	0.02	-0.01		1.00	0.01	0.00
imb_t	0.68	15.52	0.44	0.32	0.21			1.00	-0.01
$spread_t$	1.49	0.66	0.73	0.60	0.54				1.00
Italy 1-year bill									
Δp_t	-0.03	7.58	-0.01	0.04	-0.03	1.00	0.10	-0.01	0.00
$orderflow_t$	-0.01	7.58	0.03	0.03	-0.03		1.00	-0.03	0.00
imb_t	0.49	7.74	0.29	0.17	0.11			1.00	-0.01
$spread_t$	0.83	1.33	0.16	0.14	0.11				1.00

France 1-year bill									
Δp_t	0.09	4.88	-0.03	0.01	-0.01	1.00	0.10	-0.11	0.00
$orderflow_t$	-0.20	5.23	0.03	0.01	-0.03		1.00	-0.04	0.01
imb_t	-0.22	15.05	0.37	0.30	0.24			1.00	0.05
$spread_t$	1.52	0.65	0.71	0.60	0.55				1.00
Germany 2-year bond									
Δp_t	0.15	15.71	0.00	-0.02	0.01	1.00	0.04	-0.04	0.02
$orderflow_t$	-0.07	4.26	0.11	0.01	0.01		1.00	0.00	0.00
imb_t	6.27	34.18	0.39	0.30	0.26			1.00	0.01
$spread_t$	2.64	3.38	0.51	0.04	0.03				1.00
Canada 2-year bond									
Δp_t	0.33	33.36	-0.23	-0.01	0.01	1.00	0.14	-0.01	-0.01
$orderflow_t$	1.54	39.22	0.04	0.04	-0.02		1.00	0.01	0.00
imb_t	0.68	16.75	0.06	0.03	0.01			1.00	0.00
$spread_t$	1.25	4.90	0.38	0.19	0.11				1.00

Table 2: Adjusted Regressions of Price Change, Order Flow, Order Book Imbalance and Spreads

The mid-quote change, Δp_t, is the 30-minute change in mid-quote times 1000. Order book imbalance is defined as

$$imb_t = \frac{(depth\ at\ best\ bid\ price_t * best\ bid\ price_t - depth\ at\ the\ best\ ask\ price_t * best\ ask\ price_t)}{100}$$

in which $depth$ is measured in million. Order flow of the bond, $orderflow_t$, is the defined as the aggregate volume of buyer-initiated orders minus that seller-initiated order during the hour interval. The best bid ask spread is defined as the difference between the best ask price and the best bid price. We deseasonalize Δp_t, imb_t, $orderflow_t$ and $spread_t$ using the method proposed by Gallant, Rossi and Tauchen (1992). We regress each variable on a series of adjustment variables as follows:

$$x = d'l + u \qquad (2)$$

The adjustment variables we use are

1. 17 half-hourly dummies, one for each of the hours between 9:00 (GMT) and 5:30 (GMT).
2. 4 daily dummies, one for each from Monday to Thursday.
3. 11 monthly dummies, one for each from February to December

Estimation is done via ordinary least squares. Estimates with * are significant at 10% significance level and estimates with ** are significant at 5% significance level.

Panel A: French 6-month bill

	Δp_t	$orderflow_t$	imb_t	$spread_t$
intercept	0.08	-0.26	5.12**	0.79*
9:00-9:30	0.03	-0.14	-0.61	-0.23**
9:30-10:30	0.01	-0.17	-0.59	-0.27**
10:00-10:30	0.01	-0.62	-0.92	-0.29**
10:30-11:00	-0.05	0.40	-0.52	-0.32**
11:00-11:30	-0.01	0.17	-1.25	-0.32**
11:30-12:00	-0.01	-0.24	-1.32	-0.32**
12:00-12:30	0.11	0.28	-2.00*	-0.33**
12:30-13:00	-0.03	0.14	-2.40**	-0.31**
13:00-13:30	-0.02	-0.09	-1.03	-0.32**
13:30-14:00	-0.05	-0.26	-0.12	-0.33**
14:00-14:30	-0.11	-0.14	-0.52	-0.22**
14:30-15:00	-0.11	0.07	-0.59	-0.28**
15:00-15:30	0.06	-0.28	-1.90*	-0.30**
15:30-16:00	0.00	0.26	-1.85*	-0.25**
16:00-16:30	-0.01	0.19	-1.74	-0.26**
16:30-17:00	-0.04	-0.26	-1.83*	-0.22**
17:00:17:30	0.03	0.26	-0.61	-0.10**
Monday	-0.11**	-0.01	0.23	-0.05**
Tuesday	-0.06	-0.16	-0.88	-0.07**
Wednesday	-0.10*	0.09	-1.73**	-0.08**
Thursday	-0.11**	-0.22	-0.71	-0.05**
Feb	0.09	0.57	-3.32**	0.01**
Mar	0.09	0.05	-5.54**	0.10**
Apr	0.02	0.23	-5.03**	0.31**
May	0.01	0.70*	-0.30	0.35**
Jun	0.11	0.39	-5.11**	0.29**
Jul	0.02	0.34	-7.08**	0.36**
Aug	0.02	0.39	-2.87**	0.16**
Sep	0.02	0.40	-2.85**	0.16**
Oct	-0.02	0.22	-4.80**	0.19**
Nov	-0.06	0.20	-2.66**	0.40**
Dec	0.06	0.50	-4.62**	0.32**

Panel B: Italian 6-month bill

	Δp_t	$orderflow_t$	imb_t	$spread_t$
intercept	0.10	0.31	0.41	0.82*
9:00-9:30	-0.02	0.16	-0.52	-0.24**
9:30-10:30	0.08	-0.09	-0.56	-0.35**
10:00-10:30	0.28	1.00	-0.51	-0.41**
10:30-11:00	0.13	0.38	-0.99	-0.45**
11:00-11:30	0.12	0.01	-1.17*	-0.46**
11:30-12:00	0.15	-0.18	-1.02	-0.48**
12:00-12:30	0.19	0.54	-0.89	-0.47**
12:30-13:00	0.19	0.20	-0.60	-0.46**
13:00-13:30	0.17	0.06	0.33	-0.48**
13:30-14:00	0.24	1.08	-0.20	-0.43**
14:00-14:30	0.04	-0.30	0.25	-0.33**
14:30-15:00	-0.05	0.17	-0.13	-0.40**
15:00-15:30	0.19	0.37	0.10	-0.41**
15:30-16:00	0.25	0.51	-0.39	-0.31**
16:00-16:30	0.07	-0.39	-0.26	-0.35**
16:30-17:00	0.34	0.52	-0.03	-0.30**
17:00:17:30	1.48**	0.95	-0.52	0.19*
Monday	-0.52**	-0.64	-0.03	-0.17**
Tuesday	-0.42*	-0.34	-0.52	-0.18**
Wednesday	-0.45*	-0.14	-0.10	-0.12**
Thursday	-0.52**	-0.73	-0.32	-0.12**
Feb	0.10	0.02	-0.89	-0.02
Mar	0.02	0.29	1.45*	0.03
Apr	0.12	-0.38	-0.35	0.39**
May	0.79*	-0.23	-0.85	0.34*
Jun	0.19	-1.08*	1.45*	0.93**
Jul	0.03	-0.46	0.75	0.20**
Aug	0.09	-0.29	-0.60	0.31**
Sep	0.01	-1.13*	0.14	0.11
Oct	0.01	-0.51	-0.14	0.01
Nov	0.04	0.35	-7.64*	-0.03
Dec	0.11	0.26	-2.82*	0.11

Panel C: German 6-month bill

	Δp_t	$orderflow_t$	imb_t	$spread_t$
intercept	2.98**	1.30*	-6.93**	1.11**
9:00-9:30	-3.28**	0.30	-0.55	-0.18**
9:30-10:30	-3.10**	1.83**	0.28	-0.22**
10:00-10:30	-3.15**	-0.39	-0.97	-0.24**
10:30-11:00	-3.34**	-0.02	-1.08	-0.26**
11:00-11:30	-3.22**	0.63	-0.67	-0.26**
11:30-12:00	-3.15**	0.28	-1.52	-0.26**
12:00-12:30	-3.17**	-0.86	-1.89**	-0.26**
12:30-13:00	-3.20**	0.23	-1.10	-0.25**
13:00-13:30	-3.20**	-0.14	-1.10	-0.26**
13:30-14:00	-3.25**	0.26	-0.60	-0.25**
14:00-14:30	-3.29**	0.79	0.30	-0.13**
14:30-15:00	-3.27**	0.63	-0.25	-0.22**
15:00-15:30	-3.16**	0.26	0.23	-0.21**
15:30-16:00	-3.20**	0.19	0.28	-0.13**
16:00-16:30	-3.08**	0.28	-0.39	-0.13**
16:30-17:00	-3.30**	0.30	0.05	-0.08**
17:00:17:30	-3.27**	0.28	1.26	0.06**
Monday	-0.13	-0.94**	-0.55	-0.03**
Tuesday	0.73	-0.82**	-1.94**	-0.07**
Wednesday	-0.07	-0.69*	-2.16**	-0.03**
Thursday	-0.12	-0.61*	-1.04**	-0.02*
Feb	0.07	-0.64	6.04**	-0.13**
Mar	0.02	-1.36*	5.87**	-0.14**
Apr	-0.14	-0.91	7.59**	-0.01
May	0.04	-0.35	7.75**	-0.10**
Jun	0.09	-0.75	10.28**	-0.16**
Jul	0.00	-0.80	11.59**	-0.11**
Aug	-0.06	-0.98	8.54**	-0.13**
Sep	1.61*	-0.61	6.98**	-0.13**
Oct	-0.01	-1.38**	5.03**	-0.19**
Nov	-0.03	-1.19*	8.76**	-0.14**
Dec	0.03	-0.57	6.91**	0.05**

Panel D: Belgium 1-year bond

	Δp_t	$orderflow_t$	imb_t	$spread_t$
intercept	-0.22	-0.13	1.74	1.87**
9:00-9:30	0.22	-0.52	-0.69	-0.40**
9:30-10:30	0.79**	-0.40	-1.20	-0.50**
10:00-10:30	0.76**	-0.52	-0.62	-0.54**
10:30-11:00	0.11	-0.19	-1.20	-0.54**
11:00-11:30	0.51	-0.14	-2.24**	-0.57**
11:30-12:00	0.60*	-0.05	-2.07*	-0.57**
12:00-12:30	0.68**	0.05	-1.47	-0.58**
12:30-13:00	0.26	-0.12	-1.64	-0.57**
13:00-13:30	0.62*	-0.61	-2.14**	-0.56**
13:30-14:00	0.59*	0.09	-2.49**	-0.57**
14:00-14:30	0.33	-0.38	-2.01*	-0.37**
14:30-15:00	0.22	-0.56	-1.06	-0.45**
15:00-15:30	1.05**	-0.12	-1.55	-0.46**
15:30-16:00	0.70**	-0.02	-1.24	-0.36**
16:00-16:30	0.52	-0.42	-2.07*	-0.38**
16:30-17:00	0.66**	-0.42	-2.67**	-0.26**
17:00:17:30	0.69**	-0.16	-3.23**	0.06
Monday	-0.35*	-0.03	0.13	-0.07*
Tuesday	-0.23	-0.23	-0.42	-0.15**
Wednesday	-0.11	0.03	0.65	-0.08**
Thursday	-0.28	0.00	-1.03*	-0.07**
Feb	0.05	-0.27	-0.46	-0.42**
Mar	-0.18	0.67	0.95	-0.16**
Apr	-0.42	0.38	2.33**	0.31**
May	-0.32	0.80*	-0.26	0.07*
Jun	-0.05	0.53	1.61	0.16**
Jul	0.00	0.07	0.18	0.10**
Aug	0.12	0.46	1.58	0.01
Sep	0.02	0.51	1.15	0.03
Oct	-0.18	0.29	1.95*	0.12**
Nov	-0.15	0.31	-1.08	0.29**
Dec	-0.03	0.30	-0.20	0.49**

Panel E: Italian 1-year bond

	Δp_t	$orderflow_t$	imb_t	$spread_t$
intercept	-0.08	0.59	0.70	1.28**
9:00-9:30	-0.63	-0.24	0.64	-0.60**
9:30-10:30	0.67	-0.53	0.50	-0.72**
10:00-10:30	0.95*	0.38	-0.62	-0.76**
10:30-11:00	0.31	0.10	-0.18	-0.81**
11:00-11:30	0.14	-0.34	-0.05	-0.82**
11:30-12:00	0.75	0.37	-0.90*	-0.84**
12:00-12:30	0.53	-0.15	0.53	-0.81**
12:30-13:00	0.39	0.11	0.87*	-0.78**
13:00-13:30	0.53	0.13	0.85	-0.81**
13:30-14:00	0.38	-0.43	0.44	-0.81**
14:00-14:30	0.09	-0.56	0.36	-0.62**
14:30-15:00	0.41	-0.51	0.14	-0.73**
15:00-15:30	0.70	-0.23	0.10	-0.65**
15:30-16:00	0.55	-0.73	0.45	-0.57**
16:00-16:30	0.84	0.74	-0.14	-0.58**
16:30-17:00	0.56	0.34	-0.55	-0.51**
17:00:17:30	0.45	1.24**	-0.11	-0.11
Monday	-0.23	0.23	-0.37	-0.13**
Tuesday	-0.03	0.04	-0.59**	-0.12**
Wednesday	-0.47*	-0.15	-0.09	-0.05
Thursday	-0.27	-0.05	-0.27	-0.08*
Feb	0.32	-0.06	-0.58	0.04
Mar	-0.13	-0.66	0.27	0.09
Apr	-1.15**	-0.45	-0.21	0.69**
May	-0.26	-1.20**	0.34	0.35**
Jun	-0.16	-0.92*	-0.09	0.48**
Jul	-0.06	-0.49	0.34	0.25**
Aug	-0.15	-0.91*	-0.63	0.44**
Sep	-0.06	-0.85*	-0.24	0.31**
Oct	-0.07	-0.64	-0.36	0.19**
Nov	-0.14	-0.32	0.98**	0.05
Dec	-0.02	-0.03	-0.90*	0.06

Panel F: French 1-year bond

	Δp_t	$orderflow_t$	imb_t	$spread_t$
intercept	0.53	-0.83**	1.38	1.96**
9:00-9:30	-0.33	-0.12	1.71*	-0.41**
9:30-10:30	0.10	0.47	-0.25	-0.55**
10:00-10:30	0.05	-0.26	1.69	-0.59**
10:30-11:00	-0.55*	-0.38	1.25	-0.58**
11:00-11:30	-0.16	0.00	0.30	-0.62**
11:30-12:00	-0.04	-0.73**	1.60	-0.64**
12:00-12:30	0.00	0.19	0.25	-0.63**
12:30-13:00	-0.43	-0.24	0.90	-0.60**
13:00-13:30	0.01	-0.26	1.69	-0.61**
13:30-14:00	-0.27	0.31	0.97	-0.61**
14:00-14:30	-0.32	0.00	2.15**	-0.39**
14:30-15:00	-0.13	0.00	1.71*	-0.52**
15:00-15:30	0.16	-0.28	1.53	-0.54**
15:30-16:00	-0.48	-0.28	1.46	-0.47**
16:00-16:30	0.54	-0.28	1.57	-0.52**
16:30-17:00	-0.23	-0.31	1.04	-0.42**
17:00:17:30	0.05	-0.09	1.09	-0.19**
Monday	-0.44**	-0.19	-0.19	-0.10**
Tuesday	-0.19	-0.14	1.40**	-0.13**
Wednesday	-0.25	-0.07	0.95*	-0.13**
Thursday	-0.41**	0.26	-0.48	-0.04*
Feb	0.19	0.34	-2.41**	-0.27**
Mar	0.01	0.82**	-2.97**	0.00
Apr	-0.44	1.09**	-5.01**	0.34**
May	-0.19	0.99**	-5.32**	0.22**
Jun	0.07	1.20**	-3.01**	0.21**
Jul	-0.06	0.65**	-3.74**	0.17**
Aug	0.12	0.97**	-3.22**	0.03
Sep	0.00	0.48	-1.67*	0.01
Oct	-0.20	0.62*	-3.12**	0.11**
Nov	-0.27	0.80**	-3.06**	0.27**
Dec	0.08	0.99**	-2.23**	0.30**

Panel G: German 2-year bond

	Δp_t	$orderflow_t$	imb_t	$spread_t$
intercept	0.88	-0.11	11.61**	3.00*
9:00-9:30	-0.04	-0.51*	2.17	-0.27
9:30-10:30	1.33	-0.17	1.77	-0.30
10:00-10:30	1.11	0.01	2.73	-0.36
10:30-11:00	-0.11	0.11	2.17	-0.35
11:00-11:30	0.09	0.20	5.65**	-0.37
11:30-12:00	1.48	0.29	0.60	-0.38
12:00-12:30	0.81	0.18	-2.01	-0.39
12:30-13:00	0.27	-0.05	3.49	-0.33
13:00-13:30	0.71	0.22	2.97	-0.42*
13:30-14:00	0.79	0.12	2.68	0.06
14:00-14:30	-0.09	-0.03	-4.08*	0.54*
14:30-15:00	1.44	-0.11	-5.11**	-0.25
15:00-15:30	2.21**	0.06	-2.95	-0.22
15:30-16:00	0.80	0.38	-3.71	0.05
16:00-16:30	2.04*	0.20	-5.11**	0.00
16:30-17:00	-0.07	0.16	-6.48**	0.12
17:00:17:30	1.67	0.26	-6.10**	0.43*
Monday	-1.23**	-0.03	-1.68	-0.04
Tuesday	-0.54	-0.03	0.98	-0.10
Wednesday	-1.08*	-0.26	-0.37	-0.09
Thursday	-1.46**	-0.06	0.40	0.26**
Feb	0.57	0.11	-0.92	-0.20
Mar	0.18	0.05	-1.95	0.15
Apr	-1.51	0.13	-1.28	-0.14
May	-1.25	-0.34	-7.50**	-0.29
Jun	-0.76	-0.11	-5.42**	0.32
Jul	-0.84	0.22	-7.40**	-0.24
Aug	-0.68	0.06	-1.70	-0.40*
Sep	-0.26	-0.24	-8.85**	-0.32
Oct	-0.57	0.05	-7.77**	-0.37*
Nov	-1.04	0.14	-0.39	-0.53**
Dec	-0.40	0.34	-6.02*	-0.28

Panel H: Canadian 2-year bond

	Δp_t	$orderflow_t$	imb_t	$spread_t$
intercept	0.25	2.49	-2.16	1.96*
9:00-9:30	-0.93	-0.26	1.36	-0.49
9:30-10:30	4.59	-1.21	1.74	0.33
10:00-10:30	2.08	-4.90	1.43	-0.07
10:30-11:00	5.56*	0.30	3.69**	0.28
11:00-11:30	3.89	3.43	1.60	-0.08
11:30-12:00	2.09	2.14	1.83	-0.07
12:00-12:30	3.23	0.99	1.42	-0.02
12:30-13:00	3.68	2.05	4.04**	-0.10
13:00-13:30	3.79	-2.31	1.58	-0.14
13:30-14:00	3.51	-2.83	2.08	-0.09
14:00-14:30	1.10	-0.66	1.87	-0.51
14:30-15:00	4.09	-3.42	2.31	-0.99*
15:00-15:30	5.22*	2.46	1.38	-0.60
15:30-16:00	3.50	0.72	1.80	-0.62
16:00-16:30	2.43	-1.33	4.77**	-0.66
16:30-17:00	3.66	-1.25	2.26	-0.50
17:00:17:30	0.50	-1.77	1.53	0.05
Monday	0.31	2.92	0.98	-0.09
Tuesday	0.07	2.45	-0.03	-0.49**
Wednesday	-0.11	-0.43	-0.72	-0.45*
Thursday	-0.07	3.27*	1.46*	0.01
Feb	-2.15	-5.16*	-0.24	-0.87**
Mar	-2.90	-4.64	-0.26	-0.72**
Apr	-4.77*	3.92	1.04	-0.45
May	-4.45	-4.53	0.93	-0.28
Jun	-1.77	-0.36	0.46	-0.34
Jul	-2.20	-0.79	3.61**	-0.26
Aug	-1.81	-3.46	-0.84	-0.23
Sep	-5.65**	0.32	1.76	0.15
Oct	-3.37	-0.60	0.73	-0.20
Nov	-3.10	-4.21	-0.41	-0.12
Dec	-2.11	-6.66**	-0.67	0.18

Table 3: VAR Estimation Result on Non-announcement Days

The table presents the result of VAR estimation on non-announcement days.

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_P y_{t-P} + v_t$$

in which

$$y_t = [orderflow_t, imb_t, spread_t, \Delta p_t]'$$

The mid-quote change, Δp_t, is the 30-minute change in mid-quote times 1000. Order book imbalance is defined as

$$imb_t = \frac{(depth\ at\ best\ bid\ price_t * best\ bid\ price_t - depth\ at\ the\ best\ ask\ price_t * best\ ask\ price_t)}{100}$$

in which $depth$ is measured in million. Order flow of the bond, $orderflow_t$, is the defined as the aggregate volume of buyer-initiated orders minus that seller-initiated order during the hour interval. The best bid ask spread is defined as the difference between the best ask price and the best bid price. The matrix A_p's are ($p \times p$) coefficient matrices of the endogenous variables, y_t. The disturbance, v_t is a column vector with mean zero, $E(v_t) = 0$ and serially uncorrelated disturbances, and covariance matrix $E[v_t v_t'] = \Omega$. The order, p, is chosen on the basis of the AkikeInformation Criterion (AIC) and the Schwarz Information Criterion (SIC). We choose the minimal lag length out of these two criteria. T-statistics are given in paranthesis [ ]

Panel A: French 6-Month Bill

	$orderflow_t$	imb_t	$spread_t$	Δp_t
$orderflow_{t-1}$	0.020076	0.007286	5.50E-05	0.002229
	[1.04038]	[0.84377]	[0.58004]	[1.15570]
$orderflow_{t-2}$	-0.059181	0.004304	7.05E-05	0.001330
	[-3.06808]	[0.49859]	[0.74400]	[0.69011]
imb_{t-1}	-0.000391	0.395276	-0.000307	0.023812
	[-0.00897]	[20.2641]	[-1.43561]	[5.46574]
imb_{t-2}	-0.038487	0.171754	8.63E-05	0.002344
	[-0.87695]	[8.74519]	[0.40051]	[0.53434]
$spread_{t-1}$	-2.381326	1.826544	0.629912	-0.373565
	[-0.61379]	[1.05204]	[33.0519]	[-0.96339]
$spread_{t-2}$	-1.364922	-0.734126	0.138929	-0.069051
	[-0.35175]	[-0.42276]	[7.28844]	[-0.17805]
Δp_{t-1}	-0.215363	-0.147330	-0.001197	-0.070005
	[-1.07809]	[-1.64809]	[-1.22013]	[-3.50627]
Δp_{t-2}	0.193084	0.177388	0.001189	-0.034351
	[0.99847]	[2.04982]	[1.25178]	[-1.77733]
intercept	3.152052	-1.195875	0.163293	0.468381
	[1.20809]	[-1.02422]	[12.7406]	[1.79613]
Adj. R-squared	0.002661	0.249075	0.541691	0.022864
Sum sq. resids	20530075	4111344.	495.4024	205079.4
S.E. equation	86.79846	38.84263	0.426379	8.675165
F-statistic	1.911336	114.3137	404.7777	8.993775

Included observations: 2734

Panel B:Italian 6-Month Bill

	$orderflow_t$	imb_t	$spread_t$	Δp_t
$orderflow_{t-1}$	0.043862	-0.014153	3.53E-05	0.007276
	[2.07193]	[-1.51441]	[0.14496]	[3.23150]
imb_{t-1}	0.032883	0.390479	-0.000250	0.016896
	[0.74929]	[20.1547]	[-0.49466]	[3.61996]
$spread_{t-1}$	-1.598597	-0.193708	0.664166	-0.028842
	[-1.16863]	[-0.32077]	[42.1793]	[-0.19825]
Δp_{t-1}	-0.088549	0.135487	-0.004502	-0.161121
	[-0.45091]	[1.56282]	[-1.99178]	[-7.71439]
intercept	0.688576	-0.567982	0.190273	0.015635
	[0.39225]	[-0.73291]	[9.41619]	[0.08374]
Adj. R-squared	0.001108	0.150790	0.438527	0.033268
Sum sq. resids	12868418	2507961.	1705.133	145562.1
S.E. equation	75.12684	33.16599	0.864792	7.990183
F-statistic	1.633281	102.3897	446.9684	20.64986

Included observations: 2285

Panel C: German 6-Month Bill

	$orderflow_t$	imb_t	$spread_t$	Δp_t
$orderflow_{t-1}$	0.085689	0.056915	-0.000155	-5.98E-05
	[3.83907]	[2.64645]	[-0.88267]	[-0.02943]
$orderflow_{t-2}$	0.006312	-0.031062	-0.000187	0.002397
	[0.28918]	[-1.47699]	[-1.09007]	[1.20608]
imb_{t-1}	-0.185263	0.397290	0.000229	-0.000635
	[-8.18155]	[18.2094]	[1.29158]	[-0.30791]
imb_{t-2}	0.023620	0.195757	-0.000247	0.002902
	[1.02478]	[8.81454]	[-1.36507]	[1.38241]
$spread_{t-1}$	-2.797526	4.303832	0.570193	0.230330
	[-1.00220]	[1.60020]	[26.0475]	[0.90611]
$spread_{t-2}$	1.225972	-2.186272	0.173889	-0.064982
	[0.43908]	[-0.81265]	[7.94139]	[-0.25557]
Δp_{t-1}	-0.301953	-0.421441	0.005429	-0.167913
	[-1.23610]	[-1.79058]	[2.83384]	[-7.54834]
Δp_{t-2}	0.320546	0.824340	0.003779	-0.069199
	[1.31091]	[3.49888]	[1.97055]	[-3.10766]
intercept	1.074945	-3.446201	0.199374	-0.028807
	[0.51814]	[-1.72402]	[12.2545]	[-0.15248]
Adj. R-squared	0.043842	0.273490	0.495119	0.027604
Sum sq. resids	5504855.	5110510.	338.5451	45649.90
S.E. equation	52.16450	50.26135	0.409082	4.750310
F-statistic	12.64073	96.56979	249.9663	8.206882

Panel D: Belgian 12-Month Bill

	$orderflow_t$	imb_t	$spread_t$	Δp_t
$orderflow_{t-1}$	0.039523	0.020459	8.16E-05	0.003267
	[2.11222]	[1.64606]	[0.46629]	[1.12598]
$orderflow_{t-2}$	0.015200	-0.038501	-1.66E-05	-0.000426
	[0.81449]	[-3.10572]	[-0.09531]	[-0.14732]
imb_{t-1}	-0.111377	0.223620	-0.000101	0.002992
	[-4.02972]	[12.1803]	[-0.39139]	[0.69795]
imb_{t-2}	0.023556	0.158530	-9.76E-05	-0.004396
	[0.85056]	[8.61751]	[-0.37721]	[-1.02340]
$spread_{t-1}$	1.445094	-2.130572	0.606523	-0.308283
	[0.73647]	[-1.63464]	[33.0695]	[-1.01307]
$spread_{t-2}$	-2.521328	2.178534	0.154952	0.105617
	[-1.28507]	[1.67158]	[8.44921]	[0.34711]
Δp_{t-1}	-0.072443	-0.065797	0.000558	-0.018205
	[-0.59699]	[-0.81628]	[0.49175]	[-0.96734]
Δp_{t-2}	-0.312218	-0.092689	-0.000473	0.014048
	[-2.57751]	[-1.15196]	[-0.41805]	[0.74778]
intercept	2.188897	0.067879	0.347258	0.379655
	[0.79645]	[0.03718]	[13.5178]	[0.89074]
Adj. R-squared	0.007111	0.097864	0.527166	-0.000850
Sum sq. resids	24958406	11012509	2180.599	600283.6
S.E. equation	92.69053	61.57013	0.866393	14.37491
F-statistic	3.607749	40.50045	406.9651	0.690698

Included observations: 2914

Panel E: Italian 12-Month Bill

	$orderflow_t$	imb_t	$spread_t$	Δp_t
$orderflow_{t-1}$	0.043455	3.56E-06	8.45E-05	0.002277
	[2.05140]	[0.00028]	[0.17739]	[0.33084]
imb_{t-1}	0.022570	0.246273	-6.79E-05	0.036038
	[0.66718]	[12.1009]	[-0.08925]	[3.27919]
$spread_{t-1}$	-0.163440	-0.569560	0.578194	0.560958
	[-0.21444]	[-1.24220]	[33.7528]	[2.26564]
Δp_{t-1}	-0.101913	0.019954	-0.001863	-0.009385
	[-1.56646]	[0.50981]	[-1.27376]	[-0.44404]
intercept	-0.060216	0.613429	0.354035	-0.284696
	[-0.05307]	[0.89868]	[13.8826]	[-0.77238]
Adj. R-squared	0.001000	0.059563	0.332149	0.005230
Sum sq. resids	4566017.	1652534.	2306.634	481871.0
S.E. equation	44.75085	26.92203	1.005824	14.53778
F-statistic	1.571793	37.16476	284.9807	4.002022

Included observations: 2285

Panel F: French 12-Month Bill

	$orderflow_t$	imb_t	$spread_t$	Δp_t
$orderflow_{t-1}$	0.031431	0.006064	0.000763	0.011913
	[1.63097]	[0 .36155]	[2.51462]	[2.09980]
$orderflow_{t-2}$	0.001461	0.019963	-0.000220	-0.002098
	[0.07567]	[1.18829]	[-0.72411]	[-0.36918]
imb_{t-1}	0.049498	0.275364	-0.000466	0.042345
	[2.24170]	[14.3287]	[-1.33983]	[6.51390]
imb_{t-2}	-0.025434	0.153537	0.000367	0.000500
	[-1.14145]	[7.91718]	[1.04620]	[0.07617]
$spread_{t-1}$	-0.246142	0.428469	0.524008	0.166529
	[-0.20625]	[0.41251]	[27.8767]	[0.47396]
$spread_{t-2}$	-0.113223	-0.242051	0.201051	-0.330750
	[-0.09497]	[-0.23327]	[10.7067]	[-0.94231]
Δp_{t-1}	-0.063867	0.064937	0.001914	-0.028163
	[-0.96505]	[1.12738]	[1.83624]	[-1.44542]
Δp_{t-2}	0.010831	0.038441	-5.77E-06	0.004887
	[0.16598]	[0.67686]	[-0.00562]	[0.25437]
intercept	-0.940702	-0.438896	0.413235	0.340799
	[-0.51207]	[-0.27451]	[14.2817]	[0.63012]
Adj. R-squared	0.000567	0.125190	0.452815	0.018082
Sum sq. resids	8678159.	6573649.	2152.875	752193.5
S.E. equation	56.43266	49.11566	0.888845	16.61428
F-statistic	1.193905	49.88835	283.7064	7.291067

Included observations: 2734

Panel G: German 2-Year Bond

	$orderflow_t$	imb_t	$spread_t$	Δp_t
$orderflow_{t-1}$	0.027504	-0.030012	0.000620	0.046051
	[1.21415]	[-0.48553]	[0.64942]	[1.29814]
imb_{t-1}	0.018445	0.312780	-0.000849	0.048088
	[2.33929]	[14.5371]	[-2.55178]	[3.89443]
$spread_{t-1}$	0.622982	-1.384658	0.503688	0.370159
	[1.34477]	[-1.09534]	[25.7792]	[0.51022]
Δp_{t-1}	0.008402	-0.038282	-0.000681	-0.002181
	[0.58140]	[-0.97081]	[-1.11740]	[-0.09637]
intercept	-2.398355	8.437381	1.276883	-0.734578
	[-1.81348]	[2.33798]	[22.8922]	[-0.35468]
Adj. R-squared	0.002561	0.097843	0.253199	0.006514
Sum sq. resids	1324062.	9859157.	2355.230	3247160.
S.E. equation	26.01775	70.99626	1.097317	40.74435
F-statistic	2.258333	54.14252	167.1319	4.212985

Included observations: 1961

Panel G: Canadian 2-Year Bond

	$orderflow_t$	imb_t	$spread_t$	Δp_t
$orderflow_{t-1}$	-0.035331	0.007829	-0.009442	-0.057096
	[-1.49374]	[0.45351]	[-1.94623]	[-2.51608]
$orderflow_{t-2}$	-0.030906	0.017884	0.011880	0.087140
	[-1.30261]	[1.03274]	[2.44122]	[3.82810]
imb_{t-1}	0.044919	0.068797	0.003518	0.032188
	[1.39448]	[2.92614]	[0.53254]	[1.04152]
imb_{t-2}	-0.049575	0.031591	-0.003080	0.031106
	[-1.53767]	[1.34249]	[-0.46578]	[1.00565]
$spread_{t-1}$	0.185518	-0.033608	0.141985	1.640766
	[1.55178]	[-0.38515]	[5.79031]	[14.3050]
$spread_{t-2}$	-0.176643	0.042752	-0.054699	-1.074199
	[-1.42745]	[0.47333]	[-2.15505]	[-9.04789]
Δp_{t-1}	0.025187	-0.002458	0.026401	-0.081447
	[1.02320]	[-0.13682]	[5.22900]	[-3.44876]
Δp_{t-2}	-0.008555	0.004742	-0.003378	-0.252149
	[-0.36813]	[0.27958]	[-0.70866]	[-11.3100]
intercept	2.863507	1.205450	0.972649	-0.648251
	[0.76602]	[0.44182]	[1.26857]	[-0.18075]
Adj. R-squared	0.002143	0.002588	0.024373	0.184617
Sum sq. resids	45719818	24356245	1923425.	42083084
S.E. equation	159.0645	116.0984	32.62560	152.6071
F-statistic	1.487257	1.588693	6.667691	52.36831

Included observations: 1816

Table 4: Granger Causality Tests and Order of VAR

The table presents the p-values of the pair-wise Granger Caucality test and the order of each security by the AIC and BIC criterion. The mid-quote change, Δp_t, is the 30-minute change in mid-quote times 1000. Order book imbalance is defined as

$$imb_t = \frac{(depth\ at\ best\ bid\ price_t * best\ bid\ price_t - depth\ at\ the\ best\ ask\ price_t * best\ ask\ price_t)}{100}$$

in which $depth$ is measured in million. Order flow of the bond, $orderflow_t$, is the defined as the aggregate volume of buyer-initiated orders minus that seller-initiated order during the hour interval. The best bid ask spread is defined as the difference between the best ask price and the best bid price.

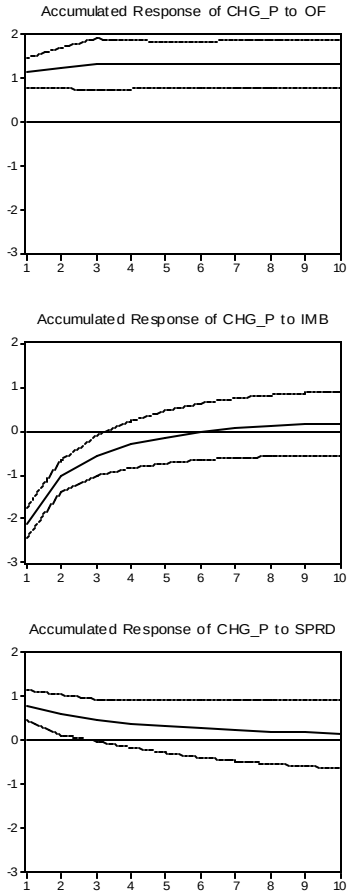
	Chi-sq Test P-value							
Excluded Variable	French 6-Month	Italian 6-Month	German 6-Month	Belgian 12-Month	Italian 12-Month	French 12-Month	German 2-Year	Canadian 2-Year
Dependent variable: $orderflow_t$								
imb_t	0.5930	0.4537	0.0000	0.0003	0.5047	0.0750	0.0193	0.1339
$spread_t$	0.4146	0.2426	0.5690	0.4223	0.8302	0.9345	0.1787	0.1573
Δp_t	0.3181	0.6521	0.1471	0.0311	0.1172	0.6171	0.5610	0.5326
Dependent variable: imb_t								
$orderflow_t$	0.6142	0.1299	0.0135	0.0025	0.9998	0.4567	0.6273	0.5356
$spread_t$	0.5048	0.7484	0.2559	0.2037	0.2142	0.9173	0.2734	0.8559
Δp_t	0.0256	0.1181	0.0001	0.3756	0.6102	0.4274	0.3316	0.9491
Dependent variable: $spread_t$								
$orderflow_t$	0.6362	0.8847	0.3432	0.8942	0.8592	0.0342	0.5161	0.0067
imb_t	0.3322	0.6208	0.3059	0.8173	0.9289	0.3358	0.0107	0.7917
Δp_t	0.1976	0.0464	0.0054	0.8087	0.2027	0.1851	0.2638	0.0000
Dependent variable: Δp_t								
$orderflow_t$	0.3987	0.0012	0.4820	0.5274	0.7408	0.1051	0.1942	0.0000
imb_t	0.0000	0.0003	0.3507	0.5377	0.0010	0.0000	0.0001	0.3232
$spread_t$	0.2710	0.8429	0.5814	0.5151	0.0235	0.6299	0.6099	0.0000
VAR Lag Order	2	1	2	2	1	2	1	2

Probability values for Wald statistics for the joint significance of each of the other lagged endogenous variables in that equation. Pairwise Granger causality tests determine whether an endogenous variable can be treated as exogenous. VAR lag order selected by the minimum of the Akaike and Schwarz information criterion

Figure 1: Response of Price change to the Order Flow, Order Book Imbalance and Spread.

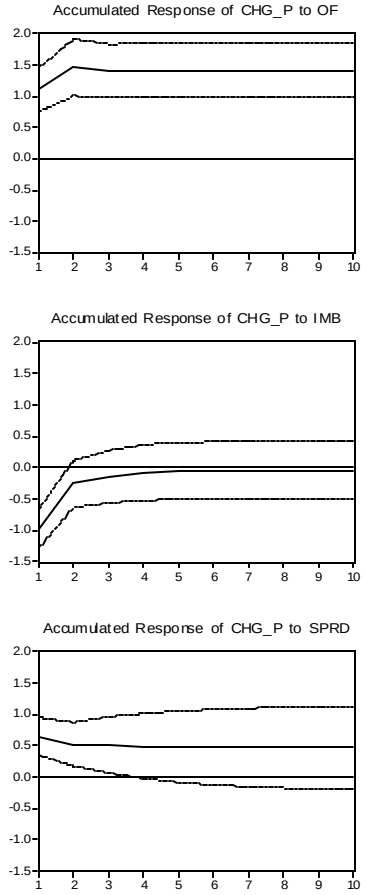
Panel A French 6-Month Bill

Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.



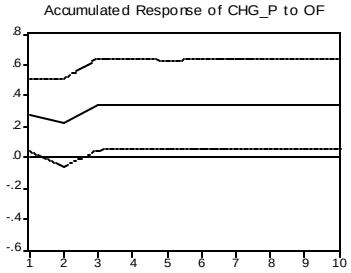
Panel B:Italian 6-Month Bill

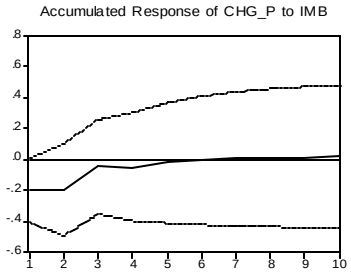
Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.

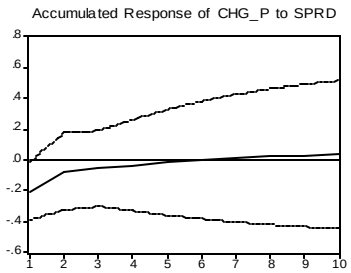


Panel C: German 6-Month Bill

Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.

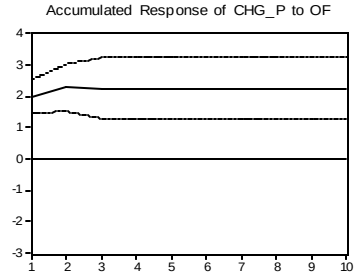


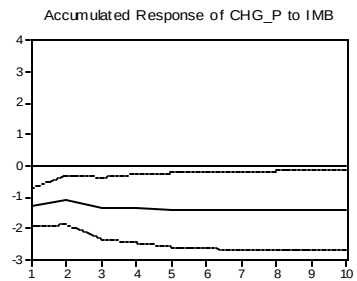


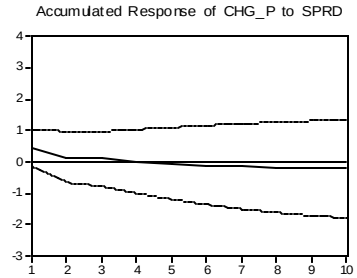


Panel D: Belgian 12-Month Bill

Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.

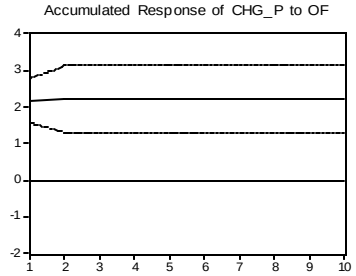


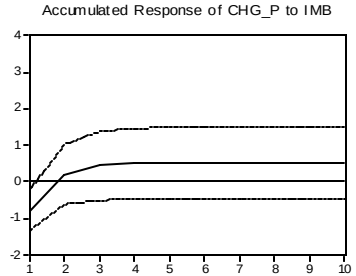


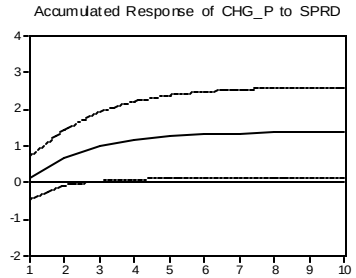


Panel E: Italian 12-Month Bill

Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.

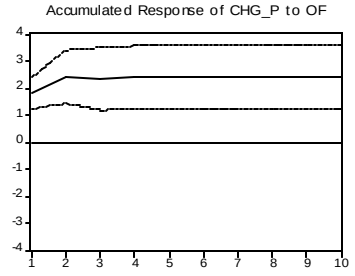


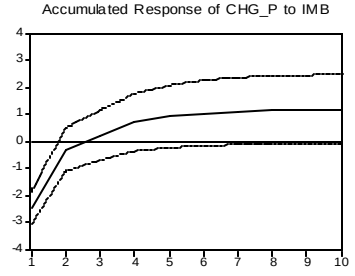


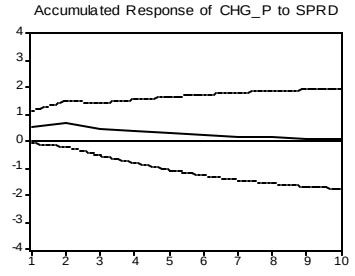


Panel F:French 12-Month Bill

Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.

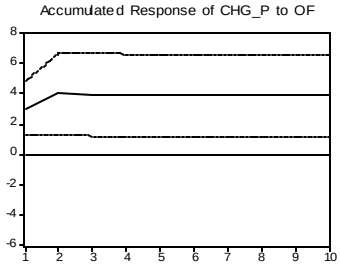


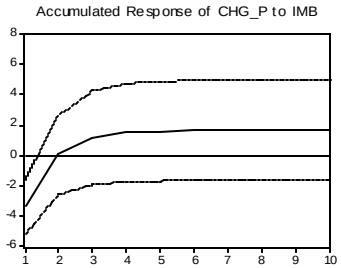


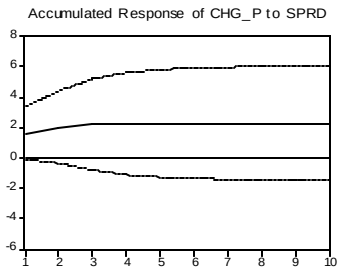


Panel G: German 2-Year Bond

Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.

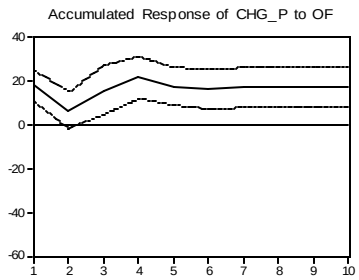


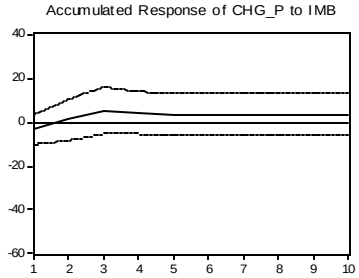




Panel H: Canadian 2-Year Bond

Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.





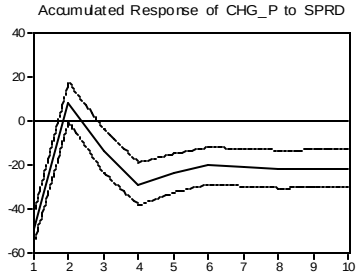


Table 5: Variance decompositions of Price Change, Order Flow, Order Book Imbalance and Spread

The table reports the percentage of the 10-period ahead forecast variance in prices due to each innovation, with each row adding up to 100. Since the variance decomposition (based on a Cholesky identification assumption) can be affected by the ordering of the variables in the VAR, both lower and upper bounds are reported by looking at all combinations of OF, IMB and SPRD in the VAR ordering. The second column, labeled "S.E.", contains the forecast error of the variable at the given forecast horizon. * indicates significance at the 95% level (Standard Errors from Monte Carlo with 100 repetitions).

	S.E	$orderflow_t$	imb_t	$spread_t$	Δp_t
French		1.728156*	7.784896*	0.931617	
6-Month	87.04116	1.589491*	7.600589*	0.765708	89.79933*
Italian		2.134629*	2.320095*	0.667858	
6-Month	75.23439	1.966932*	2.283688*	0.463754	95.08152*
German		0.429696	0.248448	0.262352	
6-Month	53.45123	0.406870	0.246450	0.253965	99.06313*
Belgian		2.009405*	0.878529	0.180340	
12-Month	93.14934	1.965706*	0.835591	0.135768	96.99641*
Italian		2.208947*	0.861392	0.229360	
12-Month	44.81252	2.107596*	0.756950	0.221510	96.81259*
French		1.303289*	4.013656*	0.124745	
12-Month	56.53160	1.298020*	3.980048*	0.088855	94.60452*
German		0.619022	1.542614*	0.170437	
2-Year	26.07777	0.557072	1.465634*	0.137933	97.75463*
Canadian		2.053549*	0.173521	22.58450*	
2-Year	159.5871	1.884926*	0.159814	22.42153*	75.35705*

Table 6: Impact of Macroeconomic Announcements

Each column reports the estimated coefficients from the regression of the VAR innovation listed at the top of each column on all the announcements. Innovations are computed from a VAR(3) for returns, order flow, order book imbalances, and spreads estimated at 30-minute intervals. All announcements are standardized to have a unit variance over the sample period. *, **, *** denote statistical significance at the 10%, 5% and 1% level respectively.

Panel A: French 6-month bill

Announcement	Δp_t		$orderflow_t$		imb_t		$spread_t$	
U.S. GDP Annualized (Final)	-4.468		5.433		6.324		-0.234	
U.S. GDP Annualized (Preliminary)	3.764		37.339	***	-30.530		-0.072	
U.S. Non-farm Productivity (Final)	6.443	**	-0.524		-0.091		-0.331	
U.S. Non-farm Productivity (Preliminary)	0.947		2.803		-0.075		0.279	**
U.S. Retail Sales Less Autos	0.363		-0.240		-4.499		0.064	
U.S. Durable Goods Orders	2.645		4.385		4.210		-0.058	
U.S. Factory Orders	0.430		-9.481		-9.746		-0.040	
U.S. PPI (MoM)	-0.324		-2.635		9.480		-0.041	
U.S. CPI (MoM)	0.637		-39.069		-46.403	***	0.456	
U.S. Housing Starts	-0.763		45.790		-39.321	***	-0.246	*
U.S. Leading Indicators	0.604		-0.701		-0.227		-0.094	
U.S. Initial Jobless Claims	-2.034	**	-6.290		0.368	*	0.384	***
Belgian Business Confidence Level	-0.038		-0.873		8.940		-0.010	
Italian GDP (QoQ)	0.247		22.921		5.595		0.373	
Italian Retail Sales (MoM)	-0.720		-23.579		7.270		0.023	
Italian Industrial Production (MoM)	0.201		0.691		29.481	**	0.099	
Italian PPI (MoM)	0.859		-38.221		-8.885		0.081	
Italian CPI (MoM)	-0.667		-0.526		-3.226		0.031	
Italian Consumer Confidence Index	0.395		-22.790		-9.243		-0.285	
French GDP (QoQ, Final)	4.444		8.737		5.337		-0.364	
French GDP (QoQ, Preliminary)	-2.489		0.505		7.678		-0.085	
French Non Farm Payrolls (QoQ)	0.783		-4.037		63.650	***	0.838	
French Industrial Production (MoM)	-2.866		-8.394		-0.424		0.004	
French Consumer Spending (MoM)	-0.099		-0.847		0.057		0.373	
French PPI (MoM)	-0.451		-0.282		2.648		-0.006	
French CPI (MoM, Final)	-0.744		2.565		0.400		-0.061	
French CPI (MoM, Prelim)	0.055		-22.550		-7.258		0.059	
French Consumer Confidence Indicator	0.436		9.359		-39.610	***	-0.046	
French Unemployment Rate	0.300		0.505		-0.089		-0.337	**
German Industrial Production (MoM)	-0.576		0.877		-0.950		-0.061	
German IFO Index Survey Bus. Climate	-9.323	**	-25.535		-0.508		0.268	
German Consumer Price Index (MoM)	-0.703		-0.047		25.365	*	-0.099	
German IFO Expectations	6.043		24.940		-8.321		-0.476	**
German Unemployment Rate	-0.784		-74.343	**	0.771		0.004	

Panel B: Italian 6-month bill

Announcement	Δp_t	$orderflow_t$		imb_t		$spread_t$	
U.S. GDP Annualized (Final)	-3.727	-6.847		-3.546	*	4.028	***
U.S. GDP Annualized (Preliminary)	2.988	-7.497	**	0.757		0.968	
U.S. Non-farm Productivity (Final)	4.879	9.504		-0.564		3.496	***
U.S. Non-farm Productivity (Preliminary)	2.793	36.805		9.053		0.868	
U.S. Retail Sales Less Autos	-4.249	-0.706		2.898		-0.370	
U.S. Durable Goods Orders	2.554	4.370		-9.280		0.436	
U.S. Factory Orders	0.404	23.933		7.444		0.092	
U.S. PPI (MoM)	4.558	-0.307		9.294		-0.775	
U.S. CPI (MoM)	-5.841	-0.006		-0.599		0.431	
U.S. Housing Starts	-0.087	8.633		-5.865	*	0.275	
U.S. Leading Indicators	0.687	-0.904		-4.829		-0.088	
U.S. Initial Jobless Claims	-0.695	-0.834		0.263		0.379	
Belgian Business Confidence Level	0.069	-6.520		4.089		-0.358	
Italian GDP (QoQ)	-8.847	-4.367		2.296		0.533	
Italian Retail Sales (MoM)	0.676	-30.203		-3.401		0.660	
Italian Industrial Production (MoM)	7.631	6.908		-7.593		-0.340	
Italian PPI (MoM)	-0.797	0.335		-0.781		-0.263	
Italian CPI (MoM)	-3.578	-4.974		-34.767	***	-0.046	
Italian Consumer Confidence Index	4.403	0.428		5.780		-0.746	
French GDP (QoQ, Final)	4.546	-25.527		0.368		-2.252	
French GDP (QoQ, Preliminary)	-4.731	-0.533		0.075		0.621	
French Non Farm Payrolls (QoQ)	-0.359	-2.055		-4.040		0.474	
French Industrial Production (MoM)	-3.370	-8.080		0.536		-0.321	
French Consumer Spending (MoM)	-5.651	-8.503		3.800		-0.842	
French PPI (MoM)	-3.808	-0.095		-4.857		0.335	
French CPI (MoM, Final)	-0.483	-35.356		0.441		0.599	
French CPI (MoM, Prelim)	-3.728	-4.025		0.325		0.267	
French Consumer Confidence Indicator	6.264	26.842		-2.029	**	-0.064	
French Unemployment Rate	2.869	0.980		7.757		-0.594	
German Industrial Production (MoM)	-0.096	-0.696		-0.400		0.305	
German IFO Index Survey Bus. Climate	-8.732	-2.628		-4.825		-0.607	
German Consumer Price Index (MoM)	6.857	29.577		-5.430		0.325	
German IFO Expectations	5.349	5.504		5.396		0.576	
German Unemployment Rate	0.443	3.466		-2.835		-0.598	

Panel C: German 6-month bill

Announcement	chg_P	OF		IMB		Spread	
U.S. GDP Annualized (Final)	-9.229	-3.993		35.977		-0.729	
U.S. GDP Annualized (Preliminary)	0.004	-4.885		5.524		-0.007	
U.S. Non-farm Productivity (Final)	5.253	-0.807		0.637		-0.020	
U.S. Non-farm Productivity (Preliminary)	-0.062	-68.454	***	0.764		-0.055	
U.S. Retail Sales Less Autos	7.783	-6.243		9.039		-0.043	
U.S. Durable Goods Orders	5.325	4.373		-4.721		-0.064	
U.S. Factory Orders	0.094	-0.069		-5.048		-0.034	
U.S. PPI (MoM)	0.276	6.876		-43.477	***	0.002	
U.S. CPI (MoM)	3.528	-0.827		6.865		-0.079	
U.S. Housing Starts	-9.337	-47.448		-0.465		0.050	
U.S. Leading Indicators	-9.771	-4.061		-40.953	***	-0.086	
U.S. Initial Jobless Claims	-0.683	0.602		-0.958		-0.034	
Belgian Business Confidence Level	3.249	-4.597		4.075		0.058	
Italian GDP (QoQ)	-6.056	-6.527		44.557	*	-0.072	
Italian Retail Sales (MoM)	-2.958	3.745		0.495		0.032	
Italian Industrial Production (MoM)	-2.700	0.054		22.866	*	-0.078	
Italian PPI (MoM)	0.980	-5.239		-3.004		-0.069	
Italian CPI (MoM)	-4.885	2.668		-0.950		0.037	
Italian Consumer Confidence Index	2.453	-8.025		0.057		-0.708	*
French GDP (QoQ, Final)	-0.974	-0.493		26.799		-0.358	**
French GDP (QoQ, Preliminary)	6.787	-3.306		-8.080		-0.246	
French Non Farm Payrolls (QoQ)	-0.656	-3.039		5.370		-0.343	**
French Industrial Production (MoM)	-0.523	-20.398		2.657		0.059	
French Consumer Spending (MoM)	-0.861	-2.253		3.284		-0.005	
French PPI (MoM)	-3.358	-3.040		-2.583		-0.331	***
French CPI (MoM, Final)	7.366	-0.653		-2.584		0.022	
French CPI (MoM, Prelim)	0.678	-0.806		-2.901		0.009	
French Consumer Confidence Indicator	0.277	-20.079		-0.694		-0.543	***
French Unemployment Rate	-0.644	-5.837		0.234		-0.053	
German Industrial Production (MoM)	-3.039	0.229		24.869	*	-0.037	
German IFO Index Survey Bus. Climate	-28.68	-52.206		2.452		0.082	
German Consumer Price Index (MoM)	0.029	0.535		2.741		-0.080	
German IFO Expectations	5.992	50.508		-3.975		-0.060	
German Unemployment Rate	-3.399	4.057		0.658		-0.006	

Panel D: Belgian 12-month bill

Announcement	chg_P		OF		IMB		Spread	
U.S. GDP Annualized (Final)	-5.441		8.789		-24.766		-0.043	
U.S. GDP Annualized (Preliminary)	5.686		3.934		3.460		-0.310	
U.S. Non-farm Productivity (Final)	7.788	***	46.803		-3.777		-0.390	
U.S. Non-farm Productivity (Preliminary)	-0.754		-3.505		-20.293		0.506	*
U.S. Retail Sales Less Autos	0.079		-0.643		7.647		0.025	
U.S. Durable Goods Orders	6.289	**	0.004		-3.839		0.087	
U.S. Factory Orders	0.983		4.997		-3.826		-0.244	
U.S. PPI (MoM)	6.860	*	3.327		47.971	**	-0.257	
U.S. CPI (MoM)	-0.428		-9.546		-48.351	*	0.309	
U.S. Housing Starts	-2.446		7.833		3.482		0.424	**
U.S. Leading Indicators	0.560		80.671	*	-0.087		-0.374	
U.S. Initial Jobless Claims	-2.399	*	-5.779		-2.010		-0.065	
Belgian Business Confidence Level	-3.470		23.837		8.771		0.050	
Italian GDP (QoQ)	-0.720		3.850		-56.423		-0.520	
Italian Retail Sales (MoM)	-0.366		53.931		-47.679	*	0.208	
Italian Industrial Production (MoM)	0.492		-7.653		-29.097		-0.044	
Italian PPI (MoM)	-0.383		-3.401		26.508		-0.075	
Italian CPI (MoM)	-0.787		-85.365	*	0.839		0.023	
Italian Consumer Confidence Index	-0.882		-44.057		4.266		-0.270	
French GDP (QoQ, Final)	4.435		-5.979		-36.690		-0.280	
French GDP (QoQ, Preliminary)	-6.771		22.935		-3.995		0.059	
French Non Farm Payrolls (QoQ)	0.649		7.557		-99.291	***	0.252	***
French Industrial Production (MoM)	0.287		0.443		-2.264		-0.565	
French Consumer Spending (MoM)	0.035		-0.625		-20.25 3		-0.275	
French PPI (MoM)	-4.377		8.065		-58.886	**	-0.441	**
French CPI (MoM, Final)	-2.028		-0.930		-3.369		0.076	
French CPI (MoM, Prelim)	-0.254		2.255		-0.841		-0.047	
French Consumer Confidence Indicator	-0.093		-2.736		25.951		-0.261	
French Unemployment Rate	0.506		-8.437		-29.921		-0.423	*
German Industrial Production (MoM)	-0.651		7.096		0.428		0.234	
German IFO Index Survey Bus. Climate	-5.677	**	-24.565		3.773		-0.324	
German Consumer Price Index (MoM)	-0.459		9.727		-22.090		0.257	
German IFO Expectations	6.545		6.401		-3.644		0.230	
German Unemployment Rate	-2.507		20.249		-8.098		-0.337	

Panel E: Italian 12-month bill

Announcement	chg_P		OF		IMB		Spread	
U.S. GDP Annualized (Final)	-3.491		-24.381		0.568		-0.399	
U.S. GDP Annualized (Preliminary)	3.830		8.960		0.644		0.009	
U.S. Non-farm Productivity (Final)	30.024	***	-3.695		-4.269		0.309	*
U.S. Non-farm Productivity (Preliminary)	0.669		-6.550		-7.947		-0.461	
U.S. Retail Sales Less Autos	0.224		-2.863		-0.253		0.031	
U.S. Durable Goods Orders	6.510		-0.405		-0.244		0.209	**
U.S. Factory Orders	-2.576		9.587		-9.769	**	0.500	
U.S. PPI (MoM)	7.092		-8.427		4.774		-0.627	
U.S. CPI (MoM)	0.068		-0.393		26.759	***	-0.365	
U.S. Housing Starts	-0.390	*	-2.668		-3.404		0.455	
U.S. Leading Indicators	-0.234		6.240		-6.579	**	-0.439	
U.S. Initial Jobless Claims	-2.290		-3.759		6.745	**	-0.869	
Belgian Business Confidence Level	-4.260		2.553		8.257	***	-0.684	
Italian GDP (QoQ)	0.003		-0.824		6.933		0.969	
Italian Retail S ales (MoM)	-4.836		-0.505		0.955		0.889	
Italian Industrial Production (MoM)	-0.793	*	-0.089		2.884		-0.004	
Italian PPI (MoM)	0.398		-0.247		-8.497		0.553	
Italian CPI (MoM)	-0.251		-0.627		5.502		-0.248	
Italian Consumer Confidence Index	6.624		7.528		2.042		-0.421	
French GDP (QoQ, Final)	7.482		-7.088		0.264		-0.441	
French GDP (QoQ, Preliminary)	-6.632		-4.883		0.486		0.001	
French Non Farm Payrolls (QoQ)	-8.556		-26.394		5.567		-0.580	
French Industrial Production (MoM)	0.247		-0.368		0.534		-0.403	
French Consumer Spending (MoM)	0.241		0.055		-3.088		0.008	
French PPI (MoM)	0.677		2.637		6.391		-0.310	
French CPI (MoM, Final)	-0.462		0.873		8.936		0.793	
French CPI (MoM, Prelim)	-3.849		-4.598		-5.534		-0.206	
French Consumer Confidence Indicator	-5.469		2.510		-24.289	***	-0.083	
French Unemployment Rate	2.903		-2.005		-7.678		-0.260	
German Industrial Production (MoM)	0.995		0.334		-0.243		0.488	
German IFO Index Survey Bus. Climate	-26.60	**	2.499		4.504		0.406	
German Consumer Price Index (MoM)	-4.361		20.650		4.050		-0.608	
German IFO Expectations	22.639	**	-9.589		-6.676		-0.673	
German Unemployment Rate	-3.529		5.656		2.339		0.291	

Panel F: French 12-month bill

Announcement	chg_P		OF		IMB		Spread	
U.S. GDP Annualized (Fin al)	-7.753	**	-38.202		3.764		-0.295	
U.S. GDP Annualized (Preliminary)	7.548		-6.074		-33.249		0.084	
U.S. Non-farm Productivity (Final)	7.375	***	7.386	**	-2.604		-0.846	***
U.S. Non-farm Productivity (Preliminary)	-4.288		-32.828		27.863		0.930	
U.S. Retail Sales Less Autos	0.895		2.693		-0.687		0.290	*
U.S. Durable Goods Orders	5.774		-5.578		-3.209		-0.060	
U.S. Factory Orders	0.780		-6.385		-6.541		-0.225	
U.S. PPI (MoM)	5.425		6.748		-5.904		-0.051	
U.S. CPI (MoM)	-3.931		-36.962		25.373		0.035	
U.S. Housing Starts	-2.009		43.232	*	-4.671		-0.091	
U.S. Leading Indicators	-0.223		2.977		-7.502		-0.300	*
U.S. Initial Jobless Claims	-3.997	**	7.844		0.569	*	0.093	
Belgian Business Confidence Level	-2.777		-2.574		-2.636		0.078	
Italian GDP (QoQ)	0.620		28.308		2.425		0.283	
Italian Retail Sales (MoM)	-2.279		0.601		-4.036		0.439	
Italian Industrial Production (MoM)	-0.608		0.454		33.358	*	0.675	
Italian PPI (MoM)	-0.978		-20.426		6.909		0.006	
Italian CPI (MoM)	-3.628		-7.706		0.770		0.078	
Italian Consumer Confidence Index	3.889		-0.883		4.589		-0.029	
French GDP (QoQ, Final)	5.501		-7.067		3.778		0.005	
French GDP (QoQ, Preliminary)	-2.989		0.055		5.428		0.406	
French Non Farm Payrolls (QoQ)	-0.646		2.910		2.747		0.995	***
French Industrial Production (MoM)	0.421		-3.877		-6.367		-0.258	
French Consumer Spending (MoM)	0.591		7.470		23.251		0.253	
French PPI (MoM)	-0.098		-3.504		-3.076		-0.202	
French CPI (MoM, Final)	0.450		-2.494		-24.026		0.654	***
French CPI (MoM, Prelim)	2.760		-9.307		-2.230		-0.963	
French Consumer Confidence Indicator	0.381		0.506		6.686		0.080	
French Unemployment Rate	0.558		-3.554		-9.308		-0.451	*
German Industrial Production (MoM)	0.359		-4.748		-0.506		-0.067	
German IFO Index Survey Bus. Climate	-7.205	**	34.684	***	3.680		0.026	
German Consumer Price Index (MoM)	-2.551		0.068		-0.474		0.037	
German IFO Expectations	8.086		-32.040	***	7.831		-0.040	
German Unemployment Rate	2.934		0.856		-3.303	**	-0.320	*

Panel G: German 2 -year bill

Announcement	chg_P		OF		IMB		Spread	
U.S. GDP Annualized (Final)	-37.84		-0.490		0.274		0.946	
U.S. GDP Annualized (Preliminary)	23.588		3.768		0.855		2.492	
U.S. Non-farm Productivity (Final)	40.225	***	-9.976		83.409		-82.354	
U.S. Non-farm Productivity (Preliminary)	-2.708		2.327		4.945		4.539	*
U.S. Retail Sales Less Autos	6.971		0.727		0.379		-0.225	
U.S. Durable Goods Orders	2.875	**	-3.284		7.765		-3.570	
U.S. Factory Orders	5.605		-0.355		-5.630		-0.360	
U.S. PPI (MoM)	7.337	*	-0.499		2.751	**	-0.066	
U.S. CPI (MoM)	6.782		-6.203		-3.692	*	-0.263	
U.S. Housing Starts	-24.87		-4.947		-38.603		-0.390	**
U.S. Leading Indicators	-0.980		0.803	*	-48.575		0.073	
U.S. Initial Jobless Claims	-3.787	*	2.350		-6.701		3.943	
Belgian Business Confidence Level	-5.876		-0.002		-0.753		-0.610	
Italian GDP (QoQ)	-5.459		0.555		69.894		-4.295	
Italian Retail Sales (MoM)	-4.739		-4.239		0.938	*	0.885	
Italian Industrial Production (MoM)	3.950		2.705		-27.330		-0.946	
Italian PPI (MoM)	0.684		2.885		6.352		0.646	
Italian CPI (MoM)	-7.648		-30.205	*	0.995		-0.034	
Italian Consumer Confidence Index	8.676		0.750		2.287		-2.293	
French GDP (QoQ, Final)	2.596		-0.541		-6.240		0.755	
French GDP (QoQ, Preliminary)	-8.580		-0.599		6.507		3.708	
French Non Farm Payrolls (QoQ)	-6.086		0.499		20.331	***	3.205	***
French Industrial Production (MoM)	3.534		0.573		37.296		-0.866	
French Consumer Spending (MoM)	-0.055		-29.930		0.264		-0.770	
French PPI (MoM)	-0.866		-3.221		2.403	**	0.634	**
French CPI (MoM, Final)	-3.804		-4.333		37.878		-0.731	
French CPI (MoM, Prelim)	-0.448		-0.688		26.478		3.049	
French Consumer Confidence Indicator	-9.755		0.633		2.548		-2.925	
French Unemployment Rate	-6.690		0.706		4.222		4.535	*
German Industrial Production (MoM)	4.600		-3.608		-7.779		0.867	
German IFO Index Survey Bus. Climate	-72.76	**	3.659		3.785		4.844	
German Consumer Price Index (MoM)	-6.680		0.633		-24.070		0.644	
German IFO Expectations	43.396		-3.338		-2.341		-4.509	
German Unemployment Rate	0.878		-0.265		4.644		0.782	

Panel H: Canadian 2-year bill

Announcement	chg_P		OF		IMB		Spread	
U.S. GDP Annualized (Final)	5.659		-7.025		-6.056		0.720	
U.S. GDP Annualized (Preliminary)	-70.660		-53.009		3.447		0.036	
U.S. Non-farm Productivity (Final)	83.863		53.446	***	5.851		-5.769	
U.S. Non-farm Productivity (Preliminary)	66.025		-46.245		39.352		0.272	
U.S. Retail Sales Less Autos	-67.826		48.588		34.769		53.743	***
U.S. Durable Goods Orders	-42.299		-0.603		47.328		3.523	
U.S. Factory Orders	-50.607		-39.681		-5.750		0.739	
U.S. PPI (MoM)	-8.749		-97.661		-4.881		-0.394	
U.S. CPI (MoM)	5.425		48.747		3.399		-6.950	
U.S. Housing Starts	82.436		4.730		26.094		-6.664	***
U.S. Leading Indicators	-38.441		-49.283		-55.955		-7.647	
U.S. Initial Jobless Claims	-2.736		64.765	*	-26.931		-4.689	
Canadian Raw Materials Prices (MoM)	-5.686		73.596		4.389		-0.550	
Canadian Current Account BOP	-4.507		56.822		-0.203		-6.364	
Canadian Retail Sales (MoM)	-84.696		7.738		5.638		-3.621	
Canadian Avg. Weekly Earnings (YoY)	9.993		2.493		2.229		5.299	
Canadian Intl. Merchandise Trade	-23.344		45.994		3.231		-0.524	
Canadian Industrial Product Price (MoM)	2.807		68.775	***	6.947		-8.476	

Figure 2: Response of endogenous variables to news innovations in Italian CPI.

FR6 stands for French 6-month bill. IT6 stands for Italian 6-month bill, DE6 stands for German 6-month bill. FR12 stands for French 1-year bill. IT12 stands for Italian 1-year bill. BE 12 stands for Belgium 1-year bill. DE24 stands for German 2-year bond.

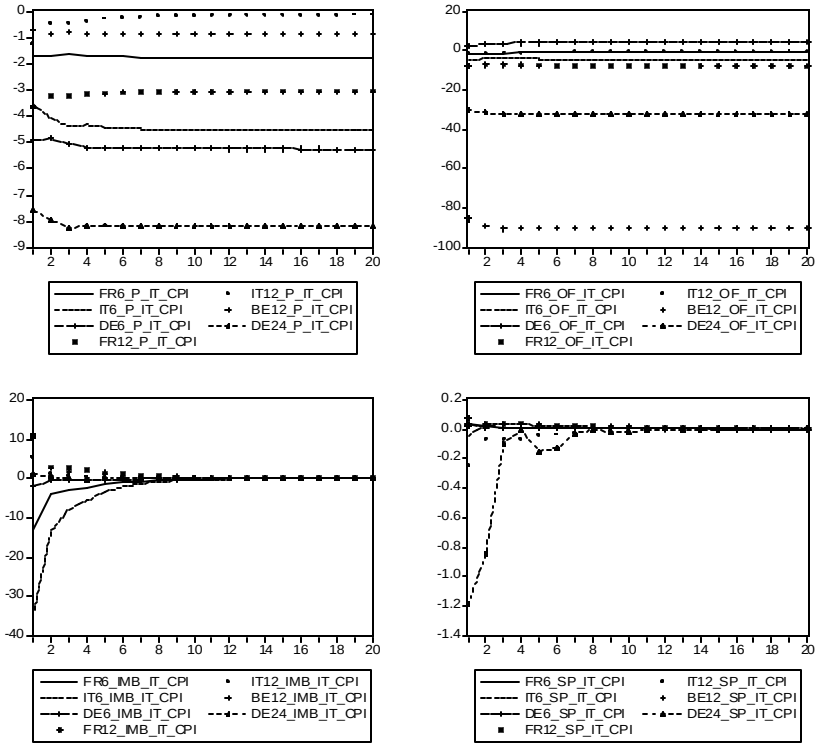


Figure 3: Response of endogenous variables to news innovations in France PPI

FR6 stands for French 6-month bill. IT6 stands for Italian 6-month bill, DE6 stands for German 6-month bill. FR12 stands for French 1-year bill. IT12 stands for Italian 1-year bill. BE 12 stands for Belgium 1-year bill. DE24 stands for German 2-year bond.

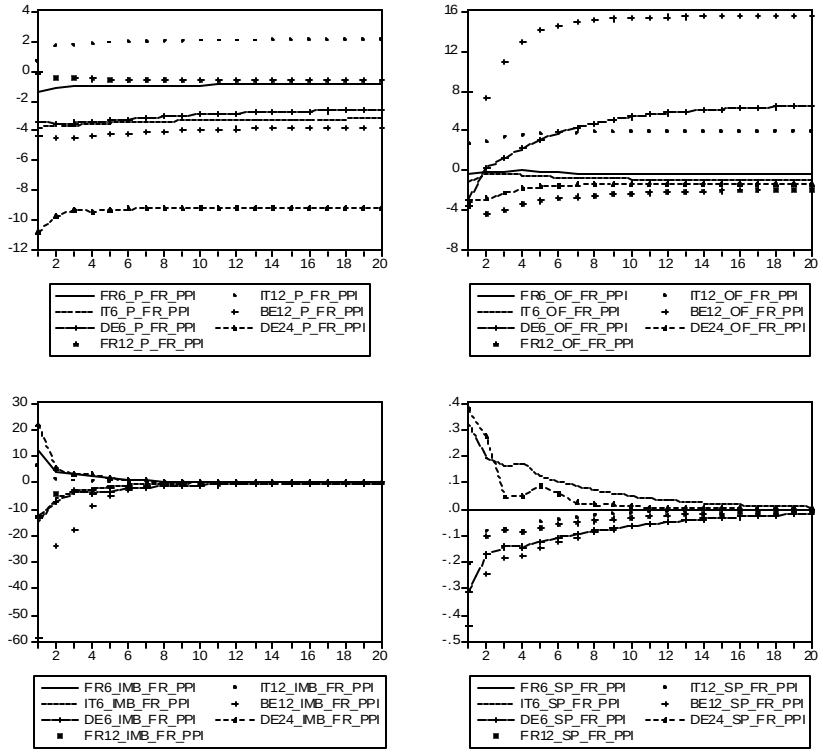


Figure 4: Response of endogenous variables to news innovations in German IFO Index Survey Bus. Climate (GE_IFOBUS)

FR6 stands for French 6-month bill. IT6 stands for Italian 6-month bill, DE6 stands for German 6-month bill. FR12 stands for French 1-year bill. IT12 stands for Italian 1-year bill. BE 12 stands for Belgium 1-year bill. DE24 stands for German 2-year bond.

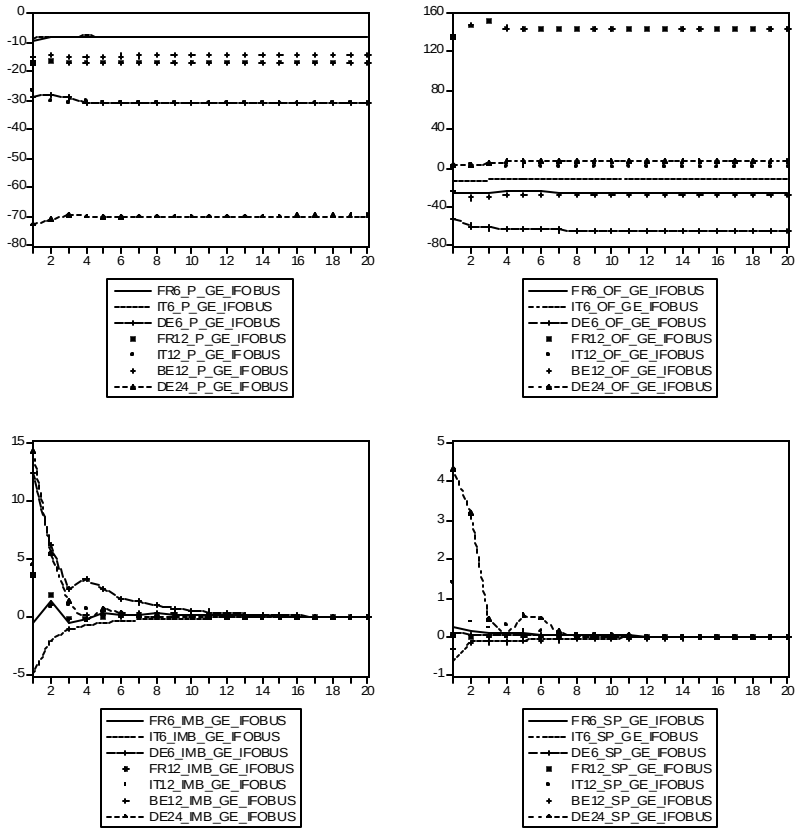


Figure 5: Response of endogenous variables to news innovations in US Non-Farm Productivity (US_NOFARM)

FR6 stands for French 6-month bill. IT6 stands for Italian 6-month bill, DE6 stands for German 6-month bill. FR12 stands for French 1-year bill. IT12 stands for Italian 1-year bill. BE 12 stands for Belgium 1-year bill. DE24 stands for German 2-year bond.

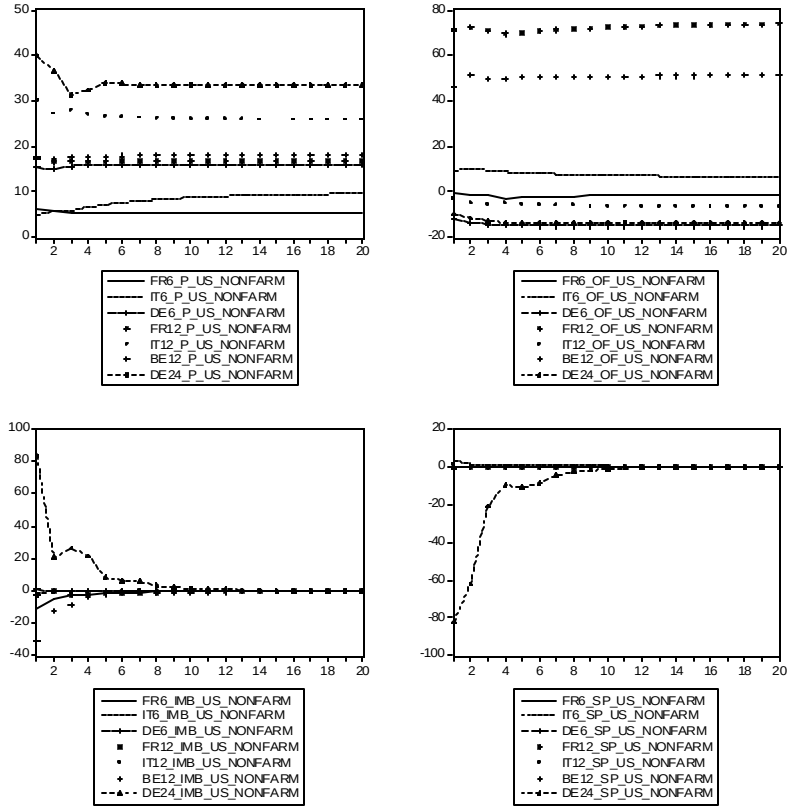


Figure 6: Response of Canadian endogenous variables to news innovations in Canada Industrial Production Price (CA_INDPROD) and US Non-Farm Productivity (US_NOFARM)

CA24 stands for Canadian 2-year bond