The Stylised Facts of Price Discovery Processes in Government Securities Markets: A Comparative Study

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Abstract

This paper investigates the price discovery process in financial markets, with a focus on government securities markets, by comparing patterns in trading volume, price volatility, and bid-ask spread in the U.S., Japan, the U.K., Italy, and Canada. The main findings are as follows. 1) In government securities markets, trading volume, price volatility, and bid-ask spread show U-shaped intraday patterns and inverse U-shaped intraweek patterns. However, equities and forex markets show different intraday and/or intraweek patterns, indicating different price discovery processes are in play. 2) Public information such as statistical announcements, notification of open market operations, and releases of policy rate changes affects the price discovery process immediately, creating surges in intraday trading volume, price volatility, and bid-ask spread. The content of this public information, including a surprise element, is important. It seems that more unexpected the surprise, the larger the surges in trading volume and price volatility. 3) The speed of price discovery seems to be faster in futures markets than in cash markets in most of the cases, partly reflecting higher accessibility and faster order-processing in futures markets. In such cases, it may be concluded that futures markets are deeper and more liquid than cash markets, in the sense that they quickly reflect incoming information, thus the degree of information content is high.

Key words: Price discovery process, government securities market, market liquidity, public information, intraday patterns, intraweek patterns

JEL classification: G10, G14

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1. Introduction

Prices of a financial product are discovered through trading activities among market participants. This process by which prices adjust to incorporate new information is referred to as the price discovery (hereafter PD) process. This paper will explore the similarities and differences, namely stylised facts, in the PD processes of the five government securities markets (U.S., Japan, U.K., Italy, and Canada) through examining the behaviour of trading volume, price volatility, and bid-ask spread, primarily based on existing studies conducted by central bank researchers in these countries.

The motivation to conduct this study is twofold. First, the study has theoretical implications. While progress in market microstructure theory has established a foothold in understanding market liquidity, the theory has not yet fully explained the various features of PD processes in markets, particularly, in fixed income securities markets. Not only central bank researchers, but also academia will benefit from the perspectives obtained through empirical analysis of whether and how the PD processes are uniquely related to the nature of the product.

Second, the study has practical implications. Understanding the PD processes themselves may further increase central banks' ability to monitor market behaviour. In addition, by observing the processes around the actual arrival of public information, central banks may gain some insight on the appropriate timing of their announcements of policy changes and statistics, as well as their notification of open market operations.

This paper mainly focuses on the government securities markets, because of their familiarity with and relevance to central banks. It also examines PD processes in the equities and forex markets, in order to shed light on the differences between PD processes according to product's different characteristics. Analyses will be conducted according to the following framework.

(1) Intraday and intraweek patterns

Information is generated 24 hours a day, 7 days a week. However, no financial market is open for such long hours. In this sense, all market participants face a price risk in not being able to trade at the prices which reflect the generated information when the market is closed. In addition, there may be some clustering of important public information at certain times of the day or week, which also affects trading activity in the market. Presumably, there are some distinct intraday and intraweek patterns of PD, reflecting market participants' behaviour in coping with these issues.

(2) PD process after arrival of public information

There must be some type of public information which systematically affects the PD process in government securities market. The paper analyses the effect of statistical announcements, notification of open market operations by central banks, and releases of policy rate changes on the PD process, as examples of such information. Presumably, some unique patterns in trading volume, price volatility, and bid-ask spread are observed after the arrival of this information.

(3) Interlinkage between the cash and futures markets

If similar products are traded in more than one market, this leads to the question of which market incorporates new information first. This question regarding PD speed is examined, with a focus on the relationship between the cash and futures government securities markets. This is based on the assumption that PD speed is a proxy for market liquidity, i.e., the market is more liquid when PD speed is high, because the degree of information content is high. Presumably, PD speed depends on relative accessibility to the two markets.

An outline of the paper's findings is as follows. 1) In government securities markets, trading volume, price volatility, and bid-ask spread show U-shaped intraday patterns and inverse U-shaped intraweek patterns. However, equities and forex markets show different intraday and/or intraweek patterns,

indicating different PD processes are in play. 2) Public information such as statistical announcements, notification of open market operations, and releases of policy rate changes immediately affects the PD process, creating surges in intraday trading volume, price volatility, and bid-ask spread. The content of this public information, including a surprise element, is important. It seems that more unexpected the surprise, the larger the surges in trading volume and price volatility. 3) The speed of price discovery seems to be faster in futures markets than in cash markets in most of the cases, partly reflecting higher accessibility and faster order-processing in futures markets. In such cases, it may be concluded that futures markets are deeper and more liquid than cash markets, in the sense that they quickly reflect incoming information, thus the degree of information content is high.

The composition of this paper is as follows: Section 2 briefly investigates the differences between PD processes in different financial markets. Section 3 focuses on intraday and intraweek patterns of trading volume, price volatility, and bid-ask spreads. Section 4 explores the PD process immediately after the arrival of public information such as statistical announcements, notification of open market operations, and announcement of policy rate changes. Section 5 deals with the interlinkage of the cash and futures government securities markets. Section 6 provides a conclusion.

2. PD process in government securities market

There are legitimate reasons why the PD processes which differ among government securities, equities, and forex markets, are affected by the relevant type and source of information. There is both public information and private information. On the one hand, public information, such as macroeconomic statistics, is released to all market participants simultaneously. In this sense, there is no information asymmetry. On the other hand, private information, such as a) inside information on an asset's fundamental value, and b) information on the order flow and on trading intentions of large customers, is presumed to be spread gradually to market participants through trading activities.

2.1 Equities vs. government securities

Standard theory on price formation of securities tells us that security prices are determined by the sum of discounted cash flow. In other words, the prices of securities are determined by two factors: expected cash flow and discount rate. The greater the cash flow, the higher the security prices would be. The higher the discount rate, the lower the security prices.

First, how are equity prices determined in relation to the type of information? The expected cash flow of equities varies according to the future earnings of the company, which are affected by both public information, such as macroeconomic indicators, and private information, such as company-specific earnings forecasts. The discount rate applied to equities is variable and is affected by both public and private information. Given these, an important caveat for equities is that the effect of public information on cash flow and discount rate often offset each other. For example, as Fleming and Remolona [1997b] stated, an upward revision of real economic activity would increase not only the expected cash flow of the company, but also the discount rate. As a result, the combined effect on equity prices is ambiguous. In sum, it may be concluded that prices of equities are primarily affected by private information.

On the other hand, in the case of government securities, the expected cash flow of government securities is fixed.[1] The discount rate applied to government securities is variable, but affected only by public information. In this sense, one may conclude that the prices of government securities are mainly affected by public information.

[1] Cash flow of index-linked bonds is not fixed, but determined solely by public information, usually the Consumer Price Index.

Of course, even in the government securities market, one cannot ignore the effects of a second type of private information, i.e., information on order flow and on trading intentions of large customers. One could argue that information asymmetry between dealers and traders could affect the PD process. However, given the fact that no one has superior insider information on the prices of government securities, the role of order flow information should be smaller in government securities markets than in equities markets. In sum, while one should not underestimate the role of order flow information, it is safe to say that the role of public information is more important in government securities markets than in equities markets.

Existing studies on the PD process in government securities market seem to be generally consistent with the above argument. For example, Proudman [1995] writes that some features of the PD process in the Gilt market are inconsistent with adverse selection models, especially trading volume and bid-ask spread immediately before and after announcements. Also, Fleming and Remolona [1998] indicate that market makers are not confronted with the risk of trading with better informed traders at the time of a major announcement in the government securities market, and market liquidity surrounding sharp price changes can be examined through inventory control models and not through asymmetric information models. In the meantime, Scalia and Vacca [1998] emphasise that the role of private information on the order flow and on the trading intentions of large customers should not be ignored.

2.2 Forex vs. government securities

In the forex market, public information, more so than private information, seems to be an important factor in the PD process, because no one has superior inside information.[2] However, the forex market differs from the government securities market, because relevant information affecting the PD process comes from two economies, because any forex market by definition has two home markets. This difference may affect the intraday and intraweek trading patterns, especially when the two economies are in different time zone.

3. Intraday and intraweek patterns[3]

In this section, cross-country comparison is conducted on the intraday and intraweek patterns of trading volume, price volatility, and bid-ask spread, which reflect the trading needs of market participants facing a price risk of being unable to trade when the market is closed, as well as public information arriving in clusters.

3.1 Intraday patterns

It may be worthwhile to briefly review the trade execution mechanisms and the trading hours for the government securities markets which are analysed below (Table 1). All countries except Japan have adopted dealer markets, where dealers or market-makers quote bid-ask prices, as their trade execution mechanism. Japan uses an auction-agency market, where buy and sell orders are continuously matched in the order-book at the centralised auction-agency. Japan and Italy's trading hours feature official opening and closing time, but there are no official opening or closing times for the U.S. and the U.K. market, although trading seems concentrated during certain periods of the day.

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[2] Of course, this does not totally exclude the influence of information asymmetry due to private information. In fact, Lyons [1995] and Ito, Lyons and Melvin [1998] show that information asymmetry does effect the forex market.

[3] Analysis of the Canadian market is not included, because no data is available at present.

Table 1

Government securities markets analysed in this paper

	U.S.	Japan	U.K.	Italy
Type of market	Interdealer	Interdealer	Customer	Interdealer
Trade execution mechanism	Dealer	Auction-agency	Dealer	Dealer
Trading hours[4]	Effectively 7:30 – 17:30	Officially 8:40 – 17:00	Effectively 8:00 – 16:15	Officially 9:00 – 17:10
Lunch break	None	11:05 – 12:25	None	None
<reference> Futures market				
Trading hours[5]	Officially 8:20 – 15:00	Officially 9:00 – 15:00	Officially 8:00 – 16:15	Officially 8:00 – 17:10
Lunch break	None	11:00 – 12:30	None	None

3.1.1 Observed features in government securities markets[6] (see Graph 1)

(a) U.S.

In the case of the interdealer market for U.S. Treasury securities, trading volume and price volatility show weak U-shape patterns. The daily peak appears between 8.30 a.m. and 9 a.m. According to Fleming [1997], this feature can be attributed to important macroeconomic announcements at 8.30 a.m., as well as the opening of U.S. Treasury futures trading at 8.20 a.m. (NY time) at the Chicago Board of Trade. The other peak between 2.30 p.m. and 3 p.m. coincides with the closing of U.S. Treasury futures trading at 3 p.m., although the second peak is less pronounced. A weak U-shaped pattern can also be observed for the bid-ask spread, but the timings of the two peaks seem to differ from the timing for trading volume and price volatility.[7]

(b) Japan

In the case of the interdealer market for Japanese government securities' trading volume and price volatility show clear U-shaped patterns. The first peak appears between 9 a.m. and 9.30 a.m. This might be primarily influenced by the opening of the bond futures market at the Tokyo Stock Exchange at 9 a.m. The scheduled release of several macroeconomic announcements at 8.50 a.m. may have caused the peak as well.[8] The second peak, which coincides with the closing of the futures market, is

4 "Effectively" refers to periods during the day when securities can be actively traded. "Officially" refers to official opening and closing times.

5 Trading hours include only the main session, and do not include evening or overnight sessions.

6 See the footnote of Graph 1 for the definition and calculation process for price volatility, which differs from study to study.

7 Although both trading volume and bid-ask spread show U-shaped patterns, the correlation coefficient is negative, i.e., when trading volume is large, the bid-ask spread tends to be tighter (Fleming [1997]). This may be because of a large spread in the very early morning and late evening when trading is thin.

8 These announcements include the Tankan (Short-term Economic Survey of Enterprises in Japan) and the Money Supply, both of which are generally considered influential by market participants.

almost as high as the first peak. After the futures market closes, trading volume and price volatility noticeably decline, even though the cash market officially closes at 5 p.m. A clear U-shaped pattern can be observed in the bid-ask spread of the futures market for Japanese government securities.[9]

(c) U.K.

Trading volume in the customer market for U.K. gilts displays a clear U-shaped pattern. The two peaks appear between 9 a.m. and 10 a.m., and between 3 p.m. and 4 p.m. According to Proudman [1995], this pattern may be a result of the release of public news being concentrated at certain times during the day. Proudman describes major economic news items are released in the U.K. in the early morning, while U.S. announcements are released in the afternoon, U.K. time. Bid-ask spread also shows a U-shaped pattern, although the pattern is not as pronounced.

(d) Italy

In the interdealer market for Italian BTPs, both trading volume and price volatility show clear U-shaped patterns. The first peak in trading volume appears between 9.30 a.m. to 10 a.m., 30 minutes after the market officially opens. The second peak in trading volume appears around 2.30–4.30 p.m. Price volatility clearly peaks twice just after the opening and just before the closing of the market. The bid-ask spread also shows a clear U-shaped pattern with peaks appearing just after the opening and before the closing of the market. In addition, there another peak appears between 1 and 1.30 p.m.

3.1.2 Stylised facts

It seems that all three parameters (trading volume, price volatility, and bid-ask spread) tend to follow U-shaped patterns in all markets. Note that the three parameters are often regarded as measures of market liquidity. It is generally understood that a market is more liquid when trading volume is high, and price volatility and the bid-ask spread are low. In this sense, the U-shaped patterns may indicate something about the intraday patterns of liquidity conditions in government securities markets.

One might explain the U-shaped pattern of trading volume in the following way. The high trading activity just after the opening of the session may be a product of a concentration of trading needs based on public information which has accumulated since the previous day's market closing. Also, high trading activity just before the closing of the session may stem from trading needs to avoid overnight price risk. The U-shaped pattern of price volatility may result from the positive relationship between trading volume and price volatility. Fleming [1997] attributes the positive volume-volatility relationship to new information or opinions being incorporated in prices through trading.

The U-shaped pattern of bid-ask spread requires more careful examination. One may simply argue that market makers tend to widen the spread when volatility is high, in order to reduce inventory risk. However, one could also point out that the large trading volume at the peaks of the U-shape may decrease the cost needed to rebalance market makers' inventory. Another hypothesis is proposed by Brock and Kleidon [1992]. They argue that, given a fixed supply of market making capacity over the short-term, market makers have some market power in the face of increased trading pressure, and they are thus obtaining higher intermediation margins relative to the true price of assets at the opening and closing of the trading session. However, as Proudman [1995] points out, it is unclear why the supply of liquidity must be held constant over the course of the day. At this moment, no theory can clearly explain the reasons for the shape.

Japan's auction-agency market shows a U-shaped pattern in its bid-ask spread. It is interesting that the bid-ask spread in an auction agency market, which is the difference between the best-bid price and the best-ask price in the order book, also follows a similar pattern to that of dealer markets. While most

[9] The bid-ask spread patterns are for the futures market, because data for bid-ask prices from the cash market is unavailable. The cash and futures markets have similar characteristics, both being auction-agency markets.

studies focus on dealer markets such as the one by Brock and Kleidon [1992], relatively small number of studies seem to tackle issues in auction-agency market.

3.1.3 Comparison to equities and forex markets

It seems that most individual research confirms that patterns in the equities market are similar to those in the government securities market. However, patterns in the forex market are considerably different from those in the government securities market.

In the U.S. equities market, existing research shows that trading volume, price volatility, and bid-ask spread generally follow a U-shape (Jain and Joh [1988], McInish and Wood [1992], Brock and Kleidon [1992], and Wood, McInish, and Ord [1985]). Muranaga [1998] finds that the Japanese equities market shows a similar pattern to that of the U.S.[10]

Forex markets have different characteristics from the equities and government securities market, because the forex market is in effect operating 24 hours a day. Andersen and Bollerslev [1998] find that, in the USD-DM market, although volatility increases in the morning for the main regional segments (Asia, Europe, New York), there is no direct evidence that this enhanced volatility is related to the termination of regional trading. This may be because traders can easily close their position easily at any time.

In sum, government securities markets behave more like equity markets than like the round-the-clock foreign exchange markets, as their U-shaped patterns for trading volume, price volatility, and bid-ask spread are similar to patterns found in equity markets, but not in forex markets (Fleming [1997]).

3.2 Intraweek patterns

The PD process for intraweek patterns, i.e., patterns according to the day of the week, is another interesting issue for investigation. While it is impossible to trade on Saturdays and Sundays, public and private information, which affects the value of a product, is continuously generated. In this sense, market participants are exposed to price risk on weekends. In addition, especially in the equities market, participants are also exposed to information asymmetry caused by the accumulation of private information on weekends. As a result, trading volume, price volatility, and bid-ask spread show distinct intraweek patterns.

3.2.1 Observed features in government securities markets (see Graph 2)

(a) U.S.

Trading volume is lowest on Mondays and Fridays, and highest on Wednesdays, which creates a clear "inverse U-shape".

(b) Japan

Trading volume is lowest on Mondays and highest on Wednesdays, also generally creating an inverse U-shape. Price volatility forms a similar pattern, although Friday's volatility is somewhat high.

(c) U.K.

Trading volume is lowest on Mondays and Fridays, and highest on Wednesdays, which creates a clear inverse U-shape. Bid-ask spread also generally shows an inverse U-shape pattern.

[10] The Canadian market also shows a similar U-shaped pattern for the Toronto Stock Exchange (McInish and Wood [1990]).

(d) Italy

Scalia [1997b] shows there is no evidence of intraweek effects for the behaviour of trading volume.

3.2.2 Stylised facts

Judging from the intraweek patterns for government securities markets in the U.S., Japan and the U.K., trading volume appears to be largest on Wednesdays, compared to that of Mondays and Fridays, which creates an inverse U-shape pattern. How can this inverse U-shape be explained?

The first hypothesis proposes that volume is low on Mondays and high on Wednesdays because market participants need a day or two to digest information, in order to evaluate and execute short-term investment strategies for the week. However, it is unclear why so much time is needed to digest information.

The second hypothesis proposes that public information such as macroeconomic announcements and decision making meetings by central banks is released in bunches on certain days of the week.[11] Presumably, the number of such releases is large on Wednesdays and small on Mondays and Fridays. However, Miyanoya, Inoue and Higo [1999] and Mitchell and Mulherin [1994] show that this hypothesis does not seem to apply to the Japanese or U.S. market, because the number of announcements are relatively large on Fridays and small on Wednesdays.[12] Of course, one may propose a hypothesis that important announcements concentrate on Fridays, but such a hypothesis has not been examined.

The third hypothesis emphasises the possibility that the number of market participants is smaller on Mondays and Fridays. This is partly explained by the time differences, i.e., the New York market is still closed on Mondays in Tokyo time, and the Tokyo market is already closed when the New York market opens on Friday. However, while this argument may partly explain Tokyo's low volume on Mondays and New York's low volume on Fridays, it is unclear why the trading volume is relatively low on Fridays in Tokyo and apparently low on Mondays in New York. One can also argue that partly due to the larger number of meetings on Mondays and Fridays, planning and summarising weekly trading strategy, there are less effective market participants on those days. However, no empirical evidence has supported this argument.

In sum, for the moment, there are no definite answers for the intraweek patterns, leaving the door open for future study.

3.2.3 Comparison to equities and forex markets[13]

While there are many individual studies of each equities market, a cross country comparison may be better achieved by using the same methodology across markets. In this regard, let us conduct a simple analysis of the intraweek patterns for trading volume and price volatility in the equities markets (Graph 3).

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[11] For example, the Councils for the Deutsche Bundesbank and Banque de France are held on Thursdays.

[12] Miyanoya, Inoue and Higo [1999] check the composition ratio for the Japanese market by the day of the week of the release dates for 14 major statistics from July 1996 to August 1997. Among the 176 releases, 28 (15.9%) are on Monday, 33 (18.8%) on Tuesday, 21 (11.9%) on Wednesday, 31 (17.6%) on Thursday, and 63 (35.8%) on Friday. Mitchell and Mulherin [1994] check the composition ratio for the U.S. market for 17 major statistics from 1983 to 1990. Of the 1,619 releases, 185 (11.4%) are on Monday, 321 (19.8%) on Tuesday, 327 (20.2%) on Wednesday, 255 (15.8%) on Thursday, and 531 (32.8%) on Friday. These results do not seem to explain the low trading volume on Mondays and Fridays, or high trading volume on Wednesdays.

[13] At the moment, existing studies on forex markets seem to be limited. One of the few empirical analyses is by Andersen and Bollerslev [1998]. They find that, while volatility is low on Mondays and high on Thursdays and Fridays in the USD-DM market, the pattern is insignificant after controlling the intraweek pattern of statistical announcements.

At first glance, trading volume seems to follow a similar inverse U-shaped pattern.[14] However, there seem to be subtle differences between the government securities and equities markets. Trading volume is lowest on Mondays and increases on Tuesdays and Wednesdays, as with government securities markets. However, with the exception of the U.K., trading volume on Fridays does not decline so much, when compared with patterns of government securities markets. In fact, in Japan, trading volume is largest on Fridays. Price volatility follows somewhat different patterns. While it is also generally high on Fridays with the exception of Italy, it not lowest on Mondays.

These differences may imply different PD processes between government securities market and equities markets. Trading volume patterns can be partly explained by the hypothesis which states that the degree of information asymmetry is presumed to be highest on Mondays and lowest on Fridays. Foster and Viswanathan [1990] point out that liquidity traders have an incentive to delay trading when they perceive a high degree of information asymmetry. They argue that, if private information accumulates over the weekend without a corresponding flow of public news announcements, trading volume tends to be smaller on Mondays and larger on Fridays, as inside information loses value as time passes. Along the same lines of this hypothesis, apparently liquidity traders also have an incentive to close their positions before the weekend to protect themselves from the accumulation of private information. Such behaviour by liquidity traders would then lead to increased trading volume on Fridays.

While high price volatility on Fridays may very well be associated with relatively large trading volume on Fridays, price volatility is relatively high on Mondays although trading volume is low on Mondays. This feature may be explained by a hypothesis which proposes that the majority of traders are likely to be informed traders on Mondays, as discussed above. It may be that market prices tend to be volatile because of the lack of liquidity traders who provide liquidity to the market.

4. PD process after the arrival of public information

It may be safe to say that government securities trading is primarily driven by the arrival of public information, contrary to equities trading where private information plays a vital role. However, not all public information affects the PD process of government securities. In this sense, it may be worth examining the PD process surrounding the arrival of influential public information, focusing on the behaviour of trading volume, price volatility, and bid-ask spreads. Let us explore the effect of statistical announcements, notification of open market operations, and releases of policy rate changes.

4.1 Statistical announcements

Indeed, statistical announcements do seem to greatly influence the PD process. As discovered in Fleming and Remolona [1997b], the largest price movements and greatest surges in trading activity are mostly associated with recently released announcements. Fleming and Remolona [1997a] note that trading volume, price volatility, and bid-ask spreads surge in the U.S. Treasury market on days when announcements are made (Graph 4). Also, by taking a closer look, they identified that these parameters take on “five stylised facts” (see Graph 5 for the actual behaviour of these parameters), which are summarised as follows.[15]

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[14] The inverse U-shaped pattern has been identified in numerous studies. Among them, Mitchell and Mulherin [1994] attribute the shape to the pattern in the volume of information. According to them, the intraweek patterns in trading volume are related to the pattern in the number of news releases by Dow and Jones & Company by the day of the week: 19.6% on Monday, 20.3% on Tuesday, 20.2% on Wednesday, 21.2% on Thursday, and 18.7% on Fridays.

[15] In the newer version of the paper (Fleming and Remolona [1998]), they analyse the adjustment process from different framework.

First, the most volatile prices occur upon announcements, at which time there is a notably low trading volume. Second, bid-ask spreads widen with volatility spikes, incurred by dealers' behaviour to control inventory risks, and narrow with surges in trading volume a few minutes later, as surges in trading volume reduce the uncertainty in transaction flows. Third, volume surges come only after lags, suggesting disagreement among dealers regarding initial price adjustments. This is because the precise magnitude of the appropriate price change is a matter for interpretation, which differs among dealers. Fourth, high price volatility and high trading volume continue for extended periods, implying a sluggish process in market participants' reconciling heterogeneous views. Finally, high volume persists for longer than high volatility, which probably reflects the behaviour of liquidity traders who employ investment strategies such as duration targeting and dynamic hedging. They react to price changes after optimal reaction lags caused by transactions costs.

Fleming and Remolona [1997b] test the surprise effect of announcements, which is defined as the difference between the forecast number and the actual number. This is based on the assumption that information may be valuable to the extent that it is unexpected. In general, it is shown that greater surprises cause greater rises/falls in price and greater surges in trading volume, although the effect is less evident in trading volume. They also test whether surges in price volatility and trading volume are larger under conditions of increased uncertainty, as measured by implied volatility from Treasury futures options. As a result, price responses to given announcement surprises are frequently greater under large uncertainty. For trading activity, market uncertainty often heightens the trading surges that follow announcement surprises.

While this kind of detailed analysis is limited to the U.S. market for the moment, increased trading volume is also associated with statistical announcements in the U.K. market as well. Proudman [1995] attributes the concentration of trading volume at certain times of the day to macroeconomic announcements in the U.K. in the early morning and in the U.S. in the afternoon in U.K. time.

Miyanoya, Inoue and Higo [1999] explore patterns for intraday trading volume and price volatility in the Japanese market on days when major statistics are released and those when they are not. They found that both trading volume and price volatility are greater on days when statistics are released (Graph 4). It is also confirmed the finding of Fleming and Remolona [1997a] that trading volume around announcements surges with a lag after volatility spikes, and continue longer than volatility (Graph 5).

Scalia [1997b] shows that, in the Italian market, while there is no empirical proof of higher trading volume after 2.30 p.m. on U.S. announcement days versus non-announcement days, there is evidence that bid-ask spread widens one hour before the release of U.S. monthly indicators at 2.30 p.m. Italian time, rising up to 4-6 basis points (Graph 4). This finding that the bid-ask spread begins to widen just before announcement, seems to coincide with findings of Fleming and Remolona [1997a].

4.2 Notification of open market operations

Notification of open market operations (OMOs) have two implications in terms of new PD in government securities markets. First, OMOs can contain some information on central bank's monetary policies, which could eventually lead to changes in securities prices. Second, as large buy/sell orders, OMOs affect supply-demand conditions for securities in the private sector to be purchased/sold, which could also influence the values of securities. These characteristics are what market participants cannot find in private transactions.

In this regard, Inoue [1999] examines the immediate effects of OMO notification by the Bank of Japan on trading volume and price volatility in the government securities market. His findings are as follows. First, only outright OMOs by the BOJ affect trading volume and price volatility. This means that market participants seem to react when public information contains some information on monetary policy and this has a long-term effect on supply-demand conditions in the securities market. In this sense, the information content of notifications seems important in the PD process. Second, changes in the purchase amounts and notification times of OMOs increase the spikes, suggesting that the level of predictability of OMO notification seems to affect smoothness of the price discovery process, i.e., the

lower/higher the predictability, the higher/lower the spikes. This may imply that a central bank should conduct its OMOs in a predictable manner when it simply wishes to provide liquidity to the market. This may also imply that a central bank could possibly send a policy signal to the market by notifying an OMO in an unexpected manner, if market participants perceive the notification as a signal of policy change.[16]

In the U.S. market, Fleming [1997] discovers that there is little evidence that activity picks up during the Federal Reserve's customary intervention time (then 11.30 a.m. to 11.45 a.m.), but price volatility seems to jump slightly during periods of Fed intervention.

4.3 Announcement of policy rate changes

Central banks' announcements of policy rate changes may be worth investigating. Although such policy rates are usually short-term interest rates, the changes likely affect future expectations for long-term interest rates. In this sense, the announcement may contain important public information affecting the value of government securities.

However, since policy rates changes usually do not occur so often, an event study may be the appropriate approach. In this regard, let us examine the behaviour of trading volume, price volatility, and bid-ask spread of JGB futures contract traded on the LIFFE, around the September 9, 1998 announcement that the Bank of Japan lowered its policy rate (overnight call rate) from "just below 0.5%" to "0.25%" (Graph 6). Such examination reveals that trading volume, price volatility, and bid-ask spread show notable increases immediately after the announcement.

4.4 Stylised facts

The features observed above can be stylised as follows. First, the arrival of public information is surely a primary factor in a new PD process. During the process, trading volume, price volatility, and bid-ask spread show a distinct pattern. It seems that bid-ask spreads tend to widen just before the arrival of public information. Trading volume may persist longer than price volatility, because of liquidity traders who rebalance their portfolios after new equilibrium prices are discovered. Market makers' behaviour to control their inventory risk seemingly plays an important role in the PD process.

Second, the information content of such announcements/notification is important. Not all announcements of statistics have the same impact. In Fleming and Remolona [1997b], several statistics such as employment data are identified as systematically having larger effect on prices. Not all OMO notification has the same impact. In Japan, only outright OMOs by the BOJ seem to immediately affect the PD process. In this sense, how market participants perceive incoming public information affects the PD process.

Third, the surprise element of an announcement is crucial in the PD process. The larger the surprise, the larger the surges in trading volume and price volatility.

5. Interlinkage of the cash and futures markets

Interlinkage of the cash and futures markets has interesting implications on the liquidity of government securities markets. In some cases, these markets can be complementary, i.e., a liquid cash market is partly the product of a well-developed futures market and vice versa. In the Japanese government securities market, a relatively liquid 10-year cash market might be the cause of a liquid

[16] It seems that sometimes the U.S. also changes the notification time of OMOs in response to the changing market environment, which market participants may perceive as a sign of possible change in the Fed's policy.

10-year futures market. In other cases, these markets can be substitutive. In the U.S. Treasury market, the cash market is more active for 5 and 10-year maturities, but the futures market is more active for 30-year maturities. This example identified by Fleming and Sarkar [1998] may show that these markets are substitutive.

In this regard, the interlinkage of price discovery between markets is an appropriate topic to investigate. There are various approaches to deal with this issue. However, partly due to the availability of data, this paper will analyse the relative speed of PD to incorporate new information.

5.1 Observed features

It seems that existing studies have adopted two approaches to this issue. The first approach, used by several studies, uses an error correction model by Garbade and Silber [1983]. This model shows how often each market incorporates new information more rapidly on a percentage basis. The second approach, taken by Miyanoya, Inoue and Higo [1999], conducts a simple time-series regression analysis.

Taking the first approach, Holland and Vila [1998] discover that, in the U.K., French, German, and Italian government securities markets, futures markets respond to new information faster than cash markets respond over 90% of the time.[17] In the Canadian market, Harvey [1996] finds that between 1993 to 1995, the BAX (futures for bankers' acceptances) market responded to new information faster than the treasury bill market 71% of the time.

Taking the second approach reveals that, in the Japanese government securities market, the price movement of the cash market lag 1–2 minutes behind that of the futures market. However, in the U.S. market, there is no lag for price movements in cash 5 and 10-year T-notes, but the price movements in 30-year cash T-bonds lag one minute behind those for T-bond futures contracts (Miyanoya, Inoue and Higo [1999]). This may be because cash transactions are generally heavier in 5 and 10-year segments, while futures transactions are heavier in 30-year segments (Fleming and Sarkar [1998]). This may imply the speed of PD increases when a market is liquid.

5.2 Stylised facts

Considering these discovered facts, it may be stylised that futures prices lead cash prices. Several factors have been identified as possible reasons. Holland and Vila [1998] focus on the accessibility of the market, arguing that initial capital outlays are smaller in the futures market than in the spot market, while investors' access to capital may be limited. Miyanoya, Inoue and Higo [1999] argue that, in Japan, different order-processing mechanisms (cash – telephone, futures – electronic) may favour faster PD in the futures market.[18]

[17] For the Italian market, Scalia [1997a] reveals that futures prices lead cash prices by between 15 and 30 minutes. For the French government securities market, Bensaid and Boutillier [1998] show that, while futures prices generally lead in stable financial conditions, but the speed of PD differs depending on the importance of information, i.e., important information is simultaneously assimilated, but less important information is first processed in the futures markets.

[18] In Japan, the different transaction tax treatment between cash and futures markets may also contribute to the faster PD in the futures market (Miyanoya, Inoue and Higo [1999]).

6. Conclusion

6.1 Summary of the findings and implications

Throughout this comparative study, the following stylised facts and possible implications are identified. First, on an intraday basis, trading volume, price volatility, and bid-ask spread show U-shaped patterns in government securities markets. However, on an intraweek basis, these three parameters show inverse U-shaped patterns in government securities markets. Meanwhile, equities and forex markets show different intraday and/or intraweek patterns, indicating different PD processes apply to different products.

Second, the arrival of public information such as statistical announcements, notification of OMOs, and releases of policy rate changes affects the PD process, creating surges in trading volume, price volatility, and bid-ask spread. The information content of an announcement/notification affects the degree of new PD. Also, in the PD process, the surprise element is important, i.e., the greater the surprise, the greater the surges in trading volume and price volatility. In this regard, it may be concluded that a central bank should notify an OMO or announce statistics and policy rate changes in a predictable manner when it wishes to mitigate the impact on trading volume and price volatility. On the other hand, a central bank may be able to send policy signals by making notifications or announcements in an unexpected manner.

Third, the speed of PD is generally faster in futures markets than in cash markets, partly reflecting higher accessibility and faster order-processing in the futures markets. This faster speed of PD may indicate that futures markets are deeper and more liquid than cash markets, in the sense that they quickly reflect incoming information, which gives them a high information content.

6.2 Areas for future study

While several stylised facts are identified in this paper, some areas for future study do remain. First, it may be worthwhile to examine the theoretical framework that applies to each market (government securities, equities, and forex) focusing on the role of information. This is because most prior efforts have concentrated on equities markets, where asymmetric information dominates. Such an endeavour to investigate the theoretical framework would shed light on the different PD processes, explaining differences between U-shaped intraday patterns and inverse U-shaped intraweek patterns in government securities markets, as well as what causes different intraday and intraweek patterns among government securities, equities, and forex markets. Ultimately, what determines market liquidity for each market (government securities, equities, and forex) is expected to be identified, taking account of the different nature of each product.

Second, another interesting area may be the interlinkage among various financial markets. Mainly due to limited data, this paper only addressed the relative speed of PD between cash and futures markets for government securities. However, the interlinkage of the two markets should have various dimensions. For example, these markets can be complementary as well as substitutive, as discussed in Section 5. In addition, one cannot discuss the market liquidity of government securities markets in isolation from other markets. It is carefully worth investigating the relationship between the cash and repo markets, or the relationship between the government securities and other fixed income securities markets.

Third, a round-the-clock PD process is also intriguing.[19] As financial activities become more globalise, financial products would be traded even more in foreign markets. However, judging from the

[19] Studies of this topic are currently being conducted almost exclusively for the U.S. market, and thus it may not be possible to draw stylised facts across countries. See Appendix for preliminary analysis.

availability of data and the number of existing studies, central banks may not have sufficient knowledge on how prices are discovered outside the domestic market. By increasing understanding of the similarities and differences in the PD process outside the home market, a central bank may gain better insight of the functioning of the financial market.

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Appendix

A round-the-clock price discovery of government securities

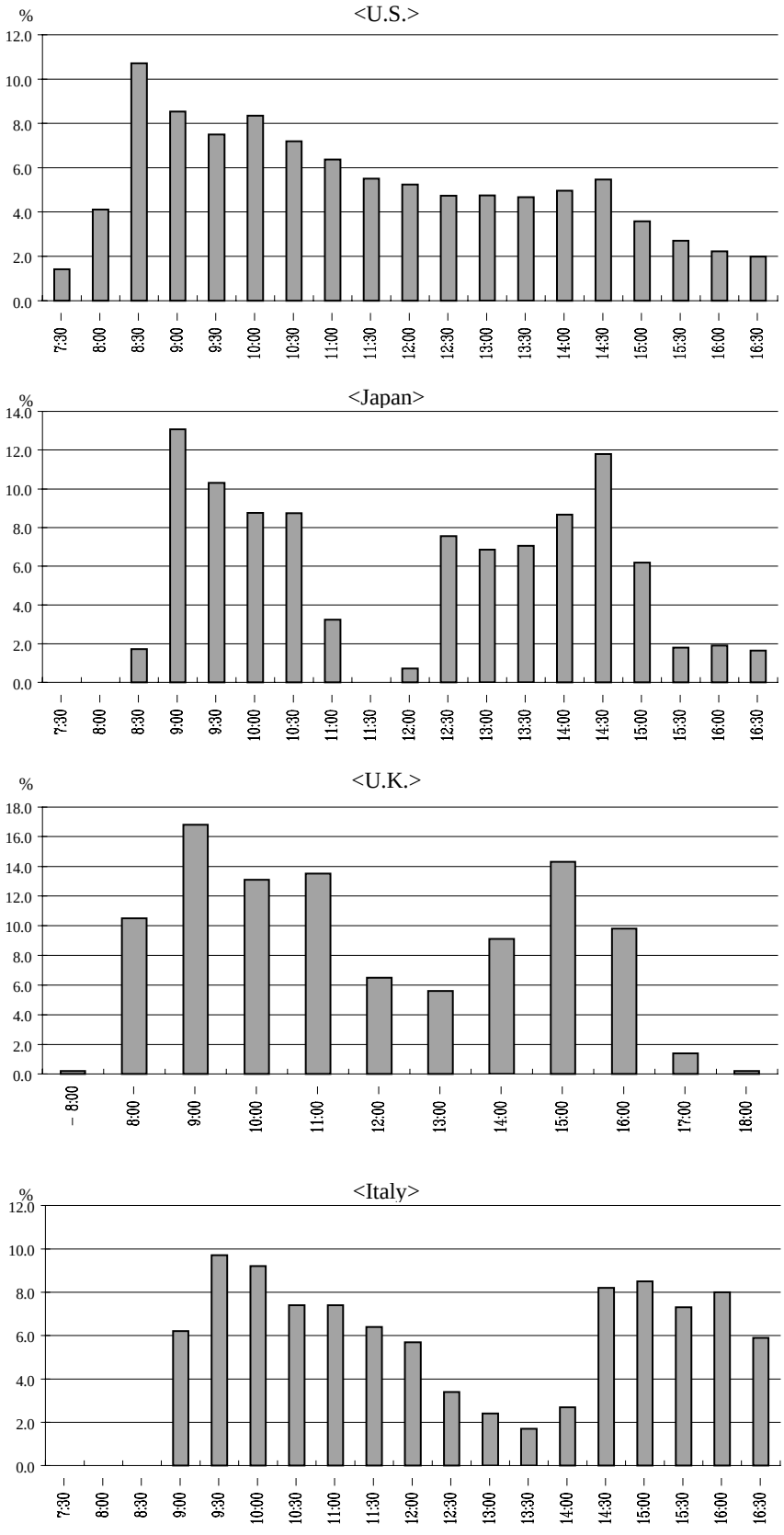
Although most government securities trading is concentrated in the domestic market, trading also occurs in foreign markets. While the availability of data is limited for trading outside the domestic market, some studies do focus on the "a round-the-clock PD process".

Fleming [1997] provides a framework that tests the degree of PD on a global scale. He investigates the predictability of opening prices for U.S. Treasury securities for a certain day in the New York market by regressing the closing prices for the same day in the Tokyo and London markets. He concludes that closing prices in Tokyo and London are unbiased predictors of overnight price changes in the New York market. This finding imply that, while the trading volume in foreign markets is relatively small, government securities prices are well discovered round-the-clock.

Fleming and Lopez [1998] present another framework which examines the possible spillover of intraday price volatility among the three trading centres (New York, Tokyo, and London) for U.S. Treasury securities. They conclude that "(Price) volatility in Tokyo and London is best characterised by the meteor shower hypothesis, with volatility spilling into these markets from the other trading centres. In contrast, we find that volatility in New York is best characterised by the heat wave hypothesis, as little evidence is found that volatility spills into New York from the other trading centres. The absence of meteor showers in New York may be explained by differences in information arrival from the other trading centres. Information arrival in the U.S. Treasury market is highly concentrated during New York trading hours. Spillovers from New York into the overseas trading centres therefore seem more likely to occur and easier to detect than spillovers from the overseas trading centres into New York". This finding is consistent with the findings of other studies that domestic information plays a vital role in the PD process for government securities.

Graph 1

Intraday Patterns of Trading Volume in Government Securities Markets



See the last page of Graph 1 for sources and notes.

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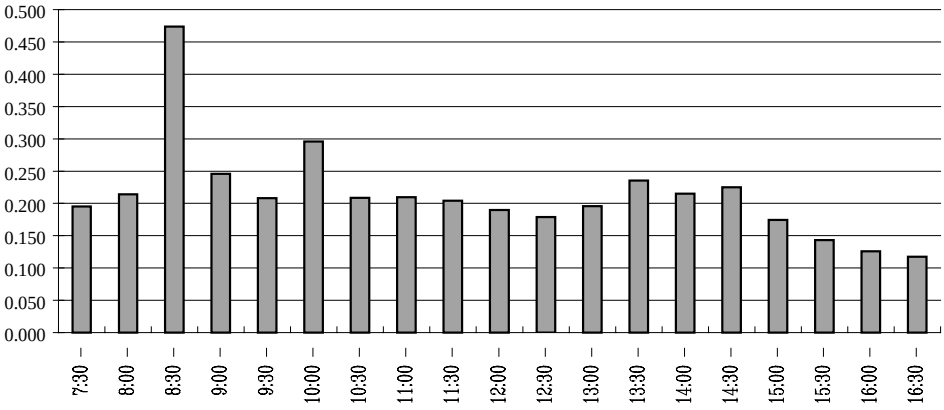

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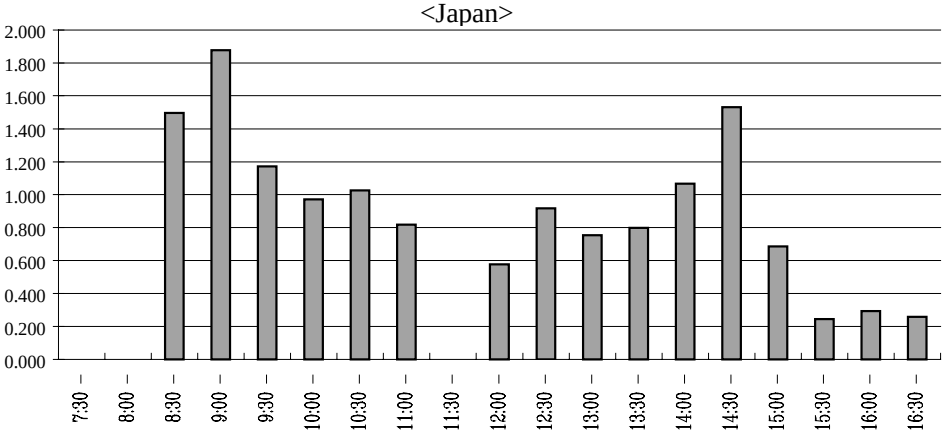
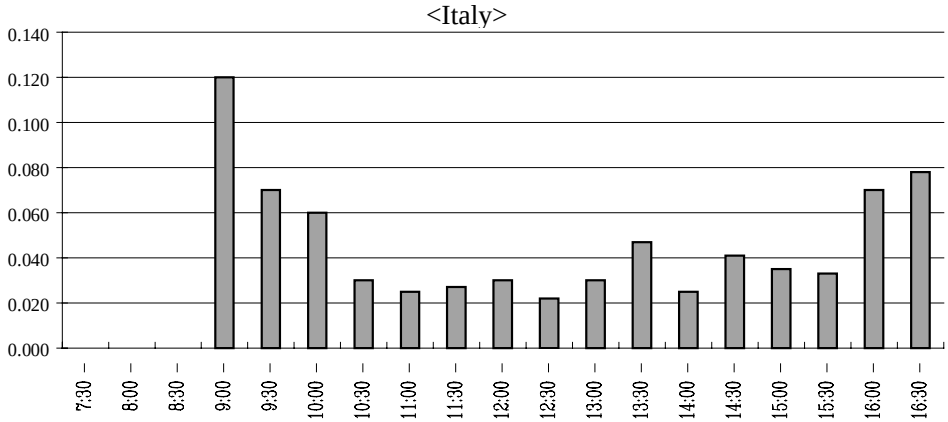


<U.K.> - n.a.

<Italy>



See the last page of Graph 1 for sources and notes.

Intraday Patterns of Bid-ask Spreads in Government Securities Markets

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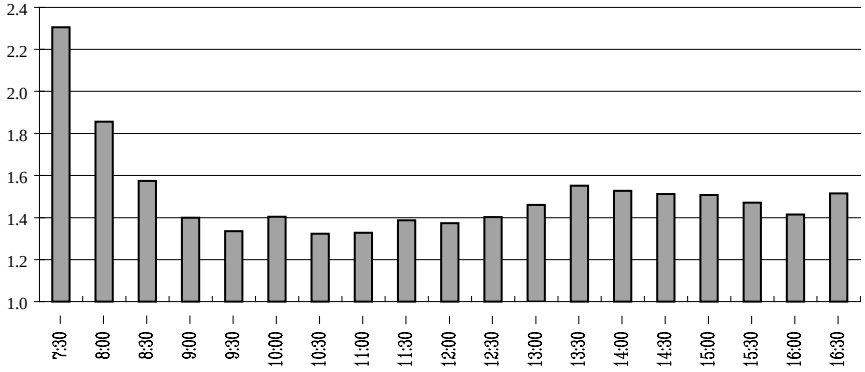

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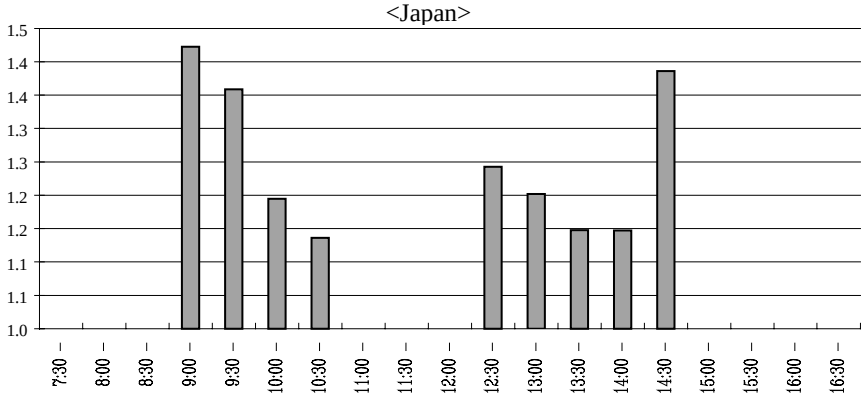

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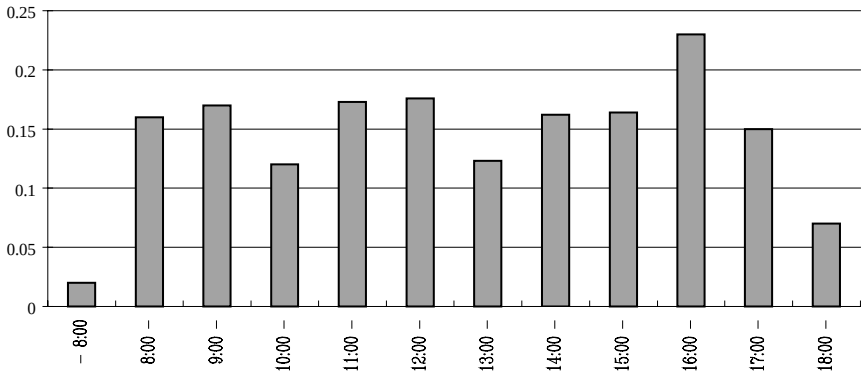

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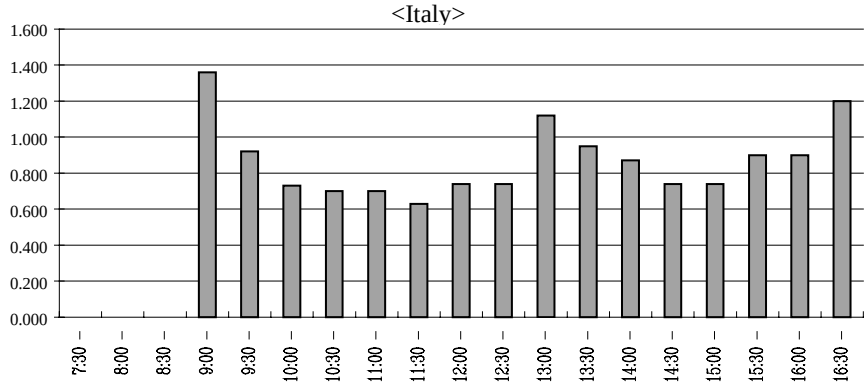

See the last page of Graph 1 for sources and notes.

Intraday Patterns of Trading Volume in Government Securities Markets

<common to all panels>

Notes: The bars show composition ratios for each 30-minute (1-hour in U.K.) segment for daily trading volume.

<U.S.>

Source: Fleming and Remolona [1997a]

Notes: The author simplified the original chart in the source which shows trading volume for each 5-minute segment. The panel shows interdealer trading volume for the benchmark 5-year Treasury note from August 23, 1993 to August 19, 1994.

<Japan>

Source: Inoue [1999]

Notes: The author simplified the original chart in the source which shows trading volume for each 5-minute segment. The panel shows interdealer trading volume for the benchmark 10-year Japanese government security from July 1996 to June 1998.

<U.K.>

Source: Proudman [1995]

Notes: The panel shows customer trading volume for three issues (6% Treasury stock 1999, 9.5% Treasury stock 2005, and 2.5% Treasury stock 2016 <index-linked>) from October 1993 to October 1994.

<Italy>

Source: Scalia and Vacca [1998]

Notes: The panel shows total interdealer trading volume from July 14, 1997 to the end of May 1998.

Intraday Patterns of Price Volatility in Government Securities Markets

<common to all panels>

Notes: The bars show price volatility for each 30-minute segment.

<U.S.>

Source: Fleming and Remolona [1997a]

Notes: The author simplified the original chart in the source which shows price volatility for each 5-minute segment. The panel shows the standard deviation of log price changes. The data are for interdealer trading for the benchmark 5-year Treasury note from August 23, 1993 to August 19, 1994. The standard deviation equals the actual standard deviation times 1,000.

<Japan>

Source: Inoue [1999]

Notes: The author simplified the original chart in the source which shows price volatility for each 5-minute segment gauged every minute. The panel shows the standard deviation of yield changes. The data are for interdealer trading for the benchmark 10-year Japanese government security from July 1996 to June 1998. The standard deviation equals the actual standard deviation times 1,000.

<Italy>

Source: Scalia and Vacca [1998]

Notes: The panel shows the squared log price difference in 30-minute intervals. The data are for interdealer trading for the benchmark 10-year BTP from July 14, 1997 to the end of May 1998.

Intraday Patterns of Bid-ask Spread in Government Securities Markets

<common to all panels>

Notes: The bars show the bid-ask spread for each 30-minute (1-hour in U.K.) segment.

<U.S.>

Source: Fleming and Remolona [1997a]

Notes: The author simplified the original chart in the source which shows spreads for each 5-minute segment. The panel shows the average spread in the interdealer trading for the benchmark 5-year Treasury note from August 23, 1993 to August 19, 1994. The spread is measured in hundredths of a percent.

<Japan>

Source: Author's calculations

Notes: The panel shows the average spread measured in 5-second intervals on the Tokyo Stock Exchange. The data are for the most active futures contract for 10-year Japanese government securities from December 1, 1997 to February 5, 1998. The spread is measured in ten thousandths of the notional face value.

<U.K.>

Source: Proudman [1995]

Notes: The panel shows the average realized spread estimated by the model developed by Roll [1984] . The data are for customer trading for three issues (6% Treasury stock 1999, 9.5% Treasury stock 2005, and 2.5% Treasury stock 2016 <index-linked>) from October 1993 to October 1994. The spread is measured by percentages of price.

<Italy>

Source: Scalia and Vacca [1998]

Notes: The panel shows the average spread estimated by the model developed by Foster and Viswanathan [1993]. The data are for interdealer trading for the benchmark 10-year BTP from July 14, 1997 to the end of May 1998. The spread is measured in ten thousandths of the face value.

Graph 2

Intraweek Patterns of Trading Volume in Government Securities Markets

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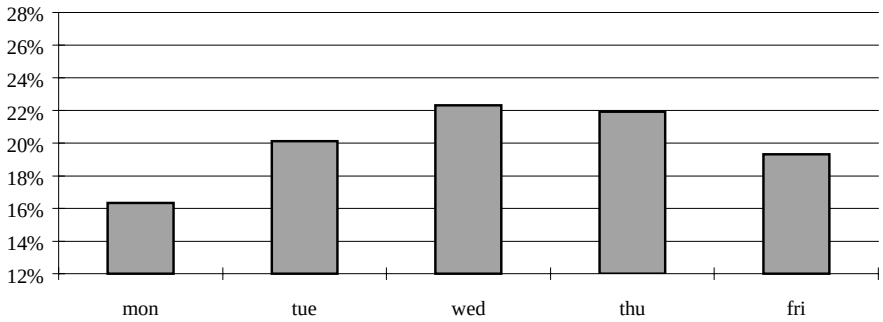

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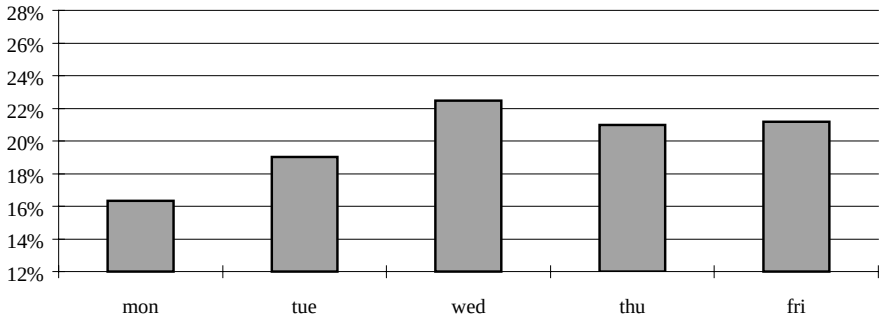

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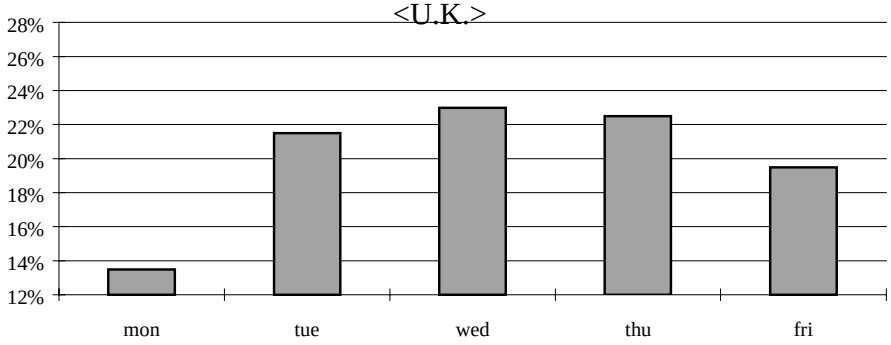


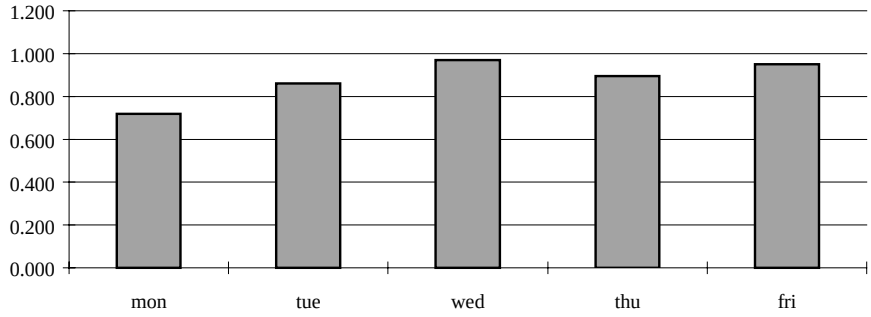
<Italy> - no intraweek pattern exists.

See the last page of Graph 2 for sources and notes.

Intraweek Patterns of Price Volatility in Government Securities Markets

<U.S.> - n.a.

<Japan>



<U.K.> - n.a.

<Italy> - no intraweek pattern exists.

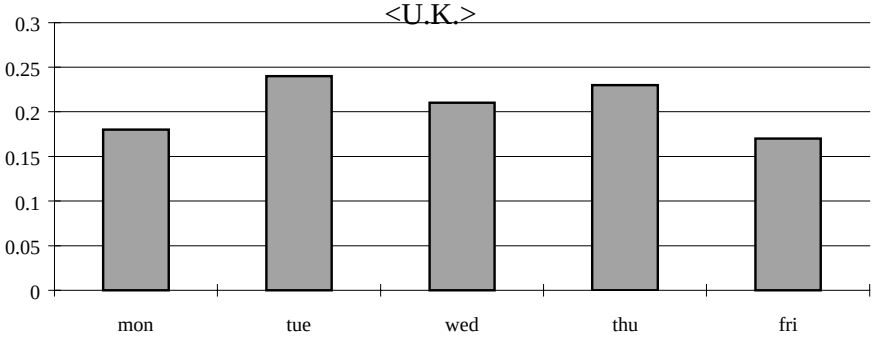
See the last page of Graph 2 for sources and notes.

Intraweek Patterns of Bid-ask Spreads in Government Securities Markets

<U.S.> - n.a.

<Japan> - n.a.

<U.K.>



<Italy> - no intraweek pattern exists.

See the last page of Graph 2 for sources and notes.

Intraweek Patterns of Trading Volume in Government Securities Markets

<common to all panels>

Notes: The bars show the composition ratios for each day of the week for weekly trading volume.

<U.S.>

Source: Data provided by Fleming

Notes: The panel shows interdealer trading volume for the benchmark 5-year Treasury note from April 4 to August 19, 1994.

<Japan>

Source: Author's calculations

Notes: The panel shows interdealer trading volume for the benchmark 10-year Japanese government security from July 1996 to June 1998.

<U.K.>

Source: Proudman [1995]

Notes: The panel shows customer trading volume for three issues (6% Treasury stock 1999, 9.5% Treasury stock 2005, and 2.5% Treasury stock 2016 <index-linked>) from October 1993 to October 1994.

Intraweek Patterns of Price Volatility in Government Securities Markets

<Japan>

Source: Author's calculations

Notes: The panel shows the standard deviation of yield changes for each 5-minute segment, gauged every minute. The data are for interdealer trading for the benchmark 10-year Japanese government security from July 1996 to June 1998. The standard deviation equals the actual standard deviation times 1,000.

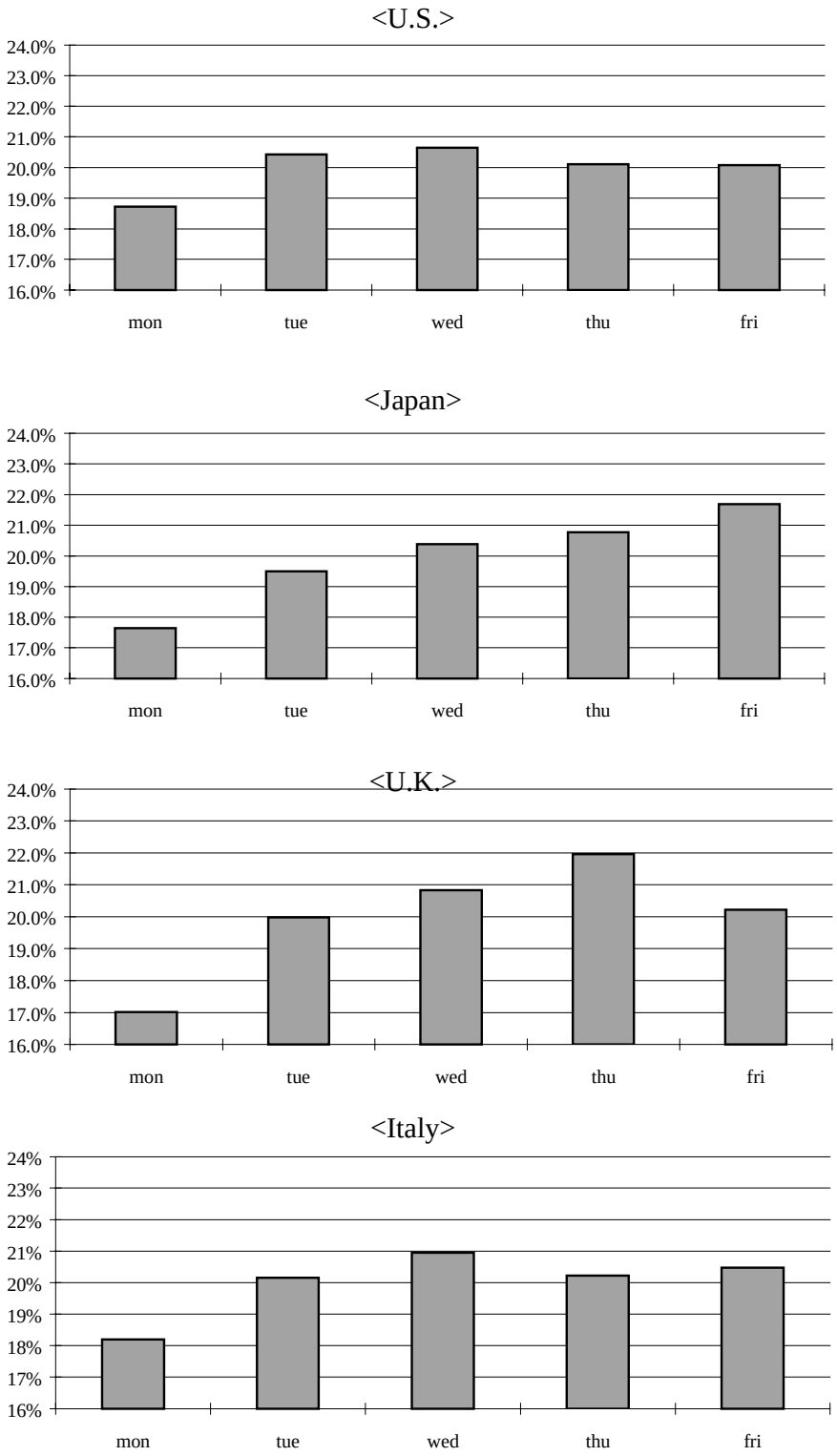
Intraweek Patterns of Bid-ask Spread in Government Securities Markets

<U.K.>

Source: Proudman [1995]

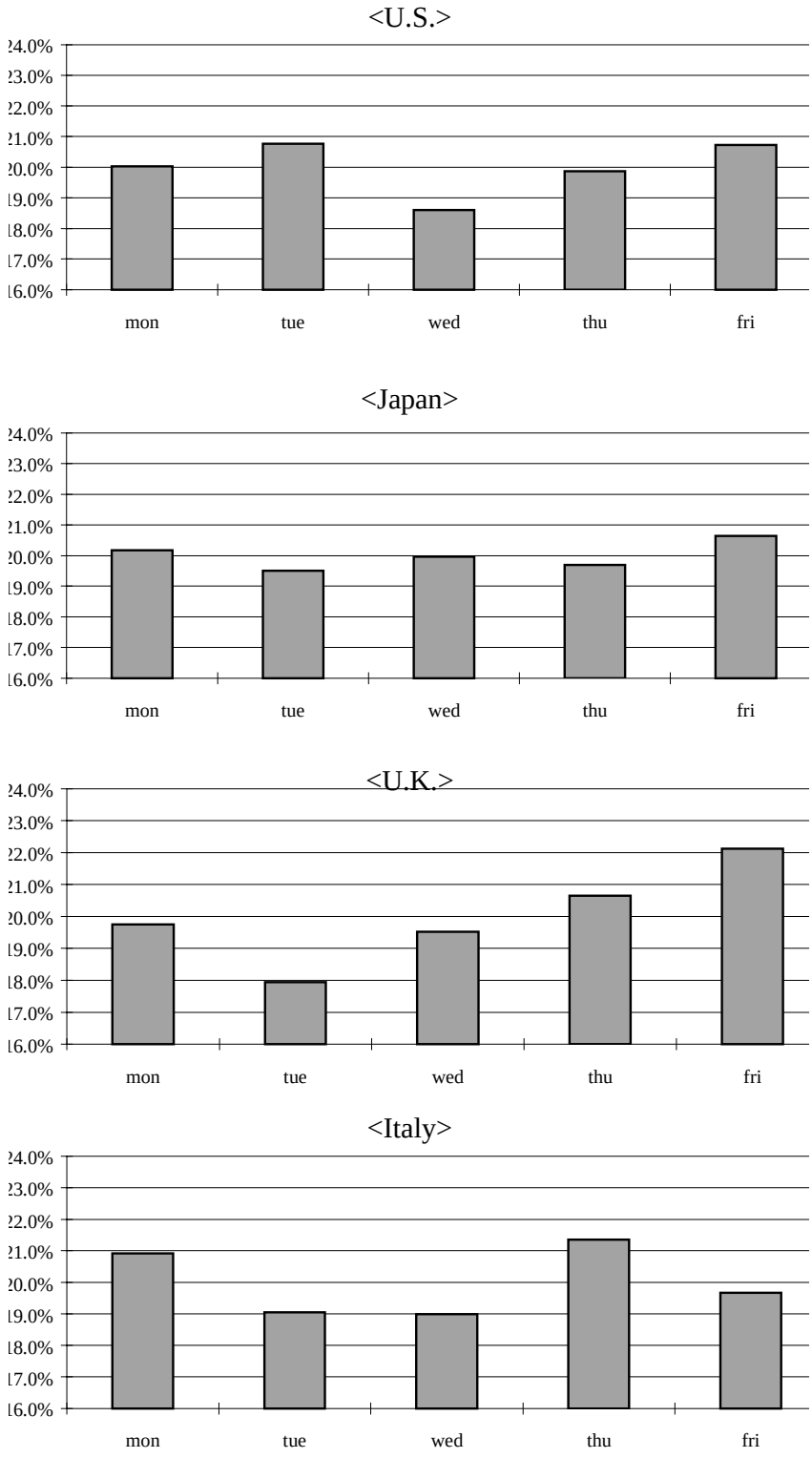
Notes: The panel shows the average realized spread estimated by the model developed by Roll [1984]. The data are for customer trading for three issues (6% Treasury stock 1999, 9.5% Treasury stock 2005, and 2.5% Treasury stock 2016 <index-linked>) from October 1993 to October 1994. The spread is measured by percentages of price.

Intraweek Patterns of Trading Volume in Equities Markets



See the last page of Graph 3 for sources and notes.

Intraweek Patterns of Price Volatility in Equities Markets



See the last page of Graph 3 for sources and notes.

Intraweek Patterns of Trading Volume in Equities Markets

<common to all panels>

Source: Author's calculations

Notes: The bars show composition ratios for each day of the week for weekly trading volume. The sample period is from October 1996 to September 1998. Days when Special Quotations are calculated for futures contracts are excluded. These days are the third Friday in U.S., U.K. and Italy, and the second Friday in Japan, in March, June, September, and December.

<U.S.>

Notes: The panel shows trading volume in the New York Stock Exchange.

<Japan>

Notes: The panel shows trading volume in the Tokyo Stock Exchange.

<U.K.>

Notes: The panel shows trading volume in the London Stock Exchange.

<Italy>

Notes: The panel shows trading volume in the Milan Stock Exchange.

Intraweek Patterns of Price Volatility in Equities Markets

<common to all panels>

Source: Author's calculations

Notes: The bars show composition ratios of price volatility for each day of the week. The price volatility is measured by the intraday price change (daily high minus daily low). The sample period is from October 1996 to September 1998. Days when Special Quotations are calculated for futures contracts are excluded, as above.

<U.S.>

Notes: The panel shows price volatility of the Dow Jones Industrial Average in the New York Stock Exchange.

<Japan>

Notes: The panel shows price volatility of the Nikkei 225 Stock Average in the Tokyo Stock Exchange.

<U.K.>

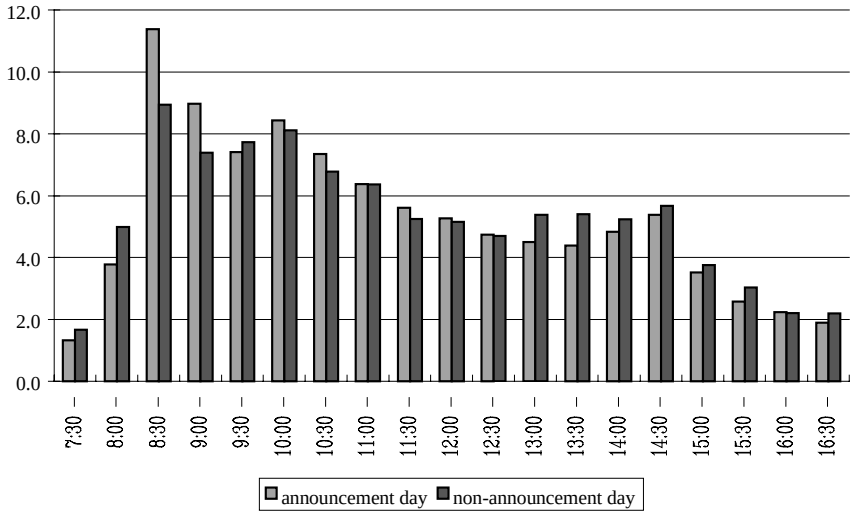
Notes: The panel shows price volatility of the FTSE 100 Index in the London Stock Exchange.

<Italy>

Notes: The panel shows price volatility of the Milan MIB Telematico Index in the Milan Stock Exchange.

Effect of Announcements on Intraday Patterns of Trading Volume

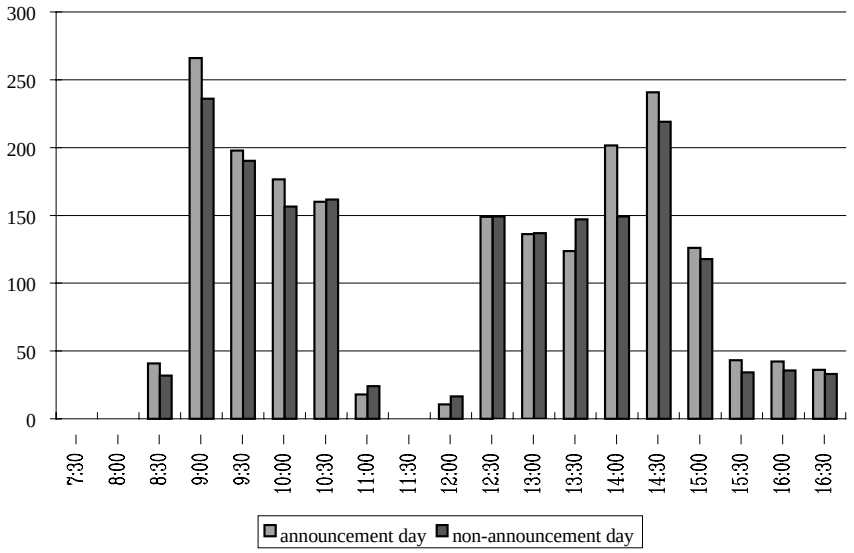
<U.S.>



Source: Fleming and Remolona [1997a]

Notes: The author simplified the original chart in the source which shows trading volume for each 5-minute segment. The panel shows interdealer trading volume for the benchmark 5-year Treasury note from August 23, 1993 to August 19, 1994. Announcement days are those days when at least one of the 19 important announcements are made.

<Japan>

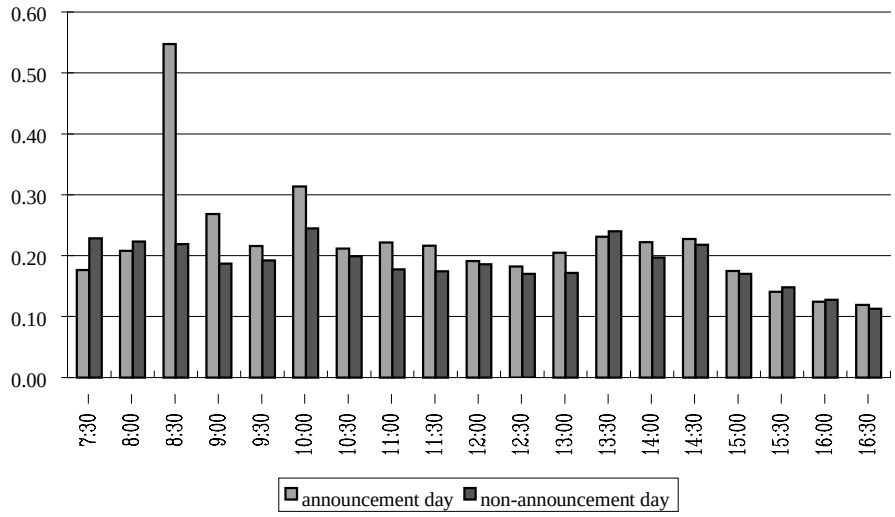


Source: Miyanoya, Inoue and Higo [1999]

Notes: The panel shows interdealer trading volume for the benchmark 10-year Japanese government security from July 1996 to August 1997. Announcement days are those days when at least one of 14 important announcements are made.

Effect of Announcements on Intraday Patterns of Price Volatility

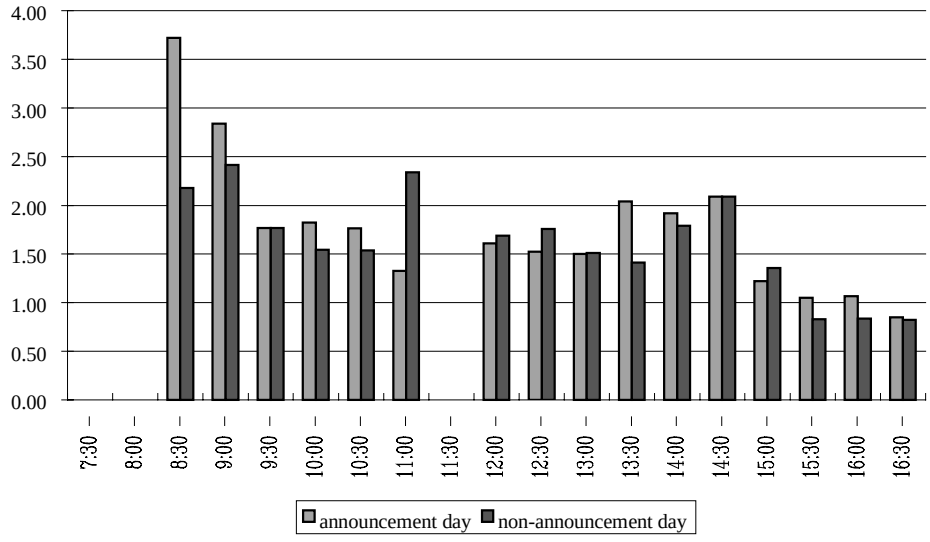
<U.S.>



Source: Fleming and Remolona [1997a]

Notes: The author simplified the original chart in the source which shows price volatility for each 5-minute segment. The panel shows the standard deviation of log price changes. The data are for interdealer trading for the benchmark 5-year Treasury note from August 23, 1993 to August 19, 1994. The standard deviation equals actual standard deviation times 1,000. Announcement days are those days when at least one of 19 important announcements are made.

<Japan>

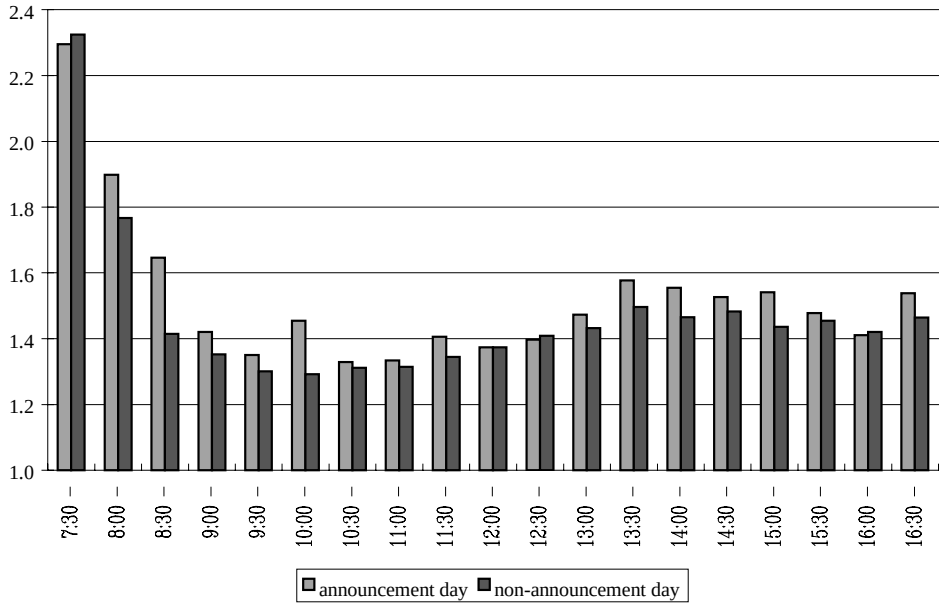


Source: Miyanoya, Inoue and Higo [1999]

Notes: The panel shows the standard deviation of yield changes. The data are for interdealer trading for the benchmark 10-year Japanese government security from July 1996 to June 1998. The standard deviation equals the actual standard deviation times 1,000. Announcement days are those days when at lest one of 14 important announcements are made.

Effect of Announcements on Intraday Patterns of Bid-ask Spread

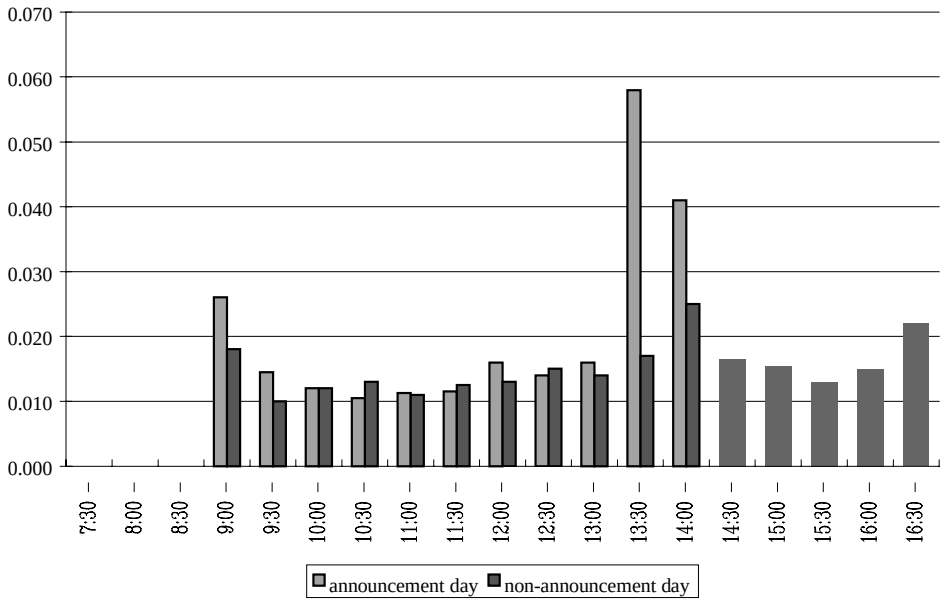
<U.S.>



Source: Fleming and Remolona [1997a]

Notes: The panel shows average spread in interdealer trading for the benchmark 5-year Treasury note from August 23, 1993 to August 19, 1994. The spread is measured in hundredth of one percent. Announcement days are those days when at least one of the 19 important announcements are made.

<Italy>

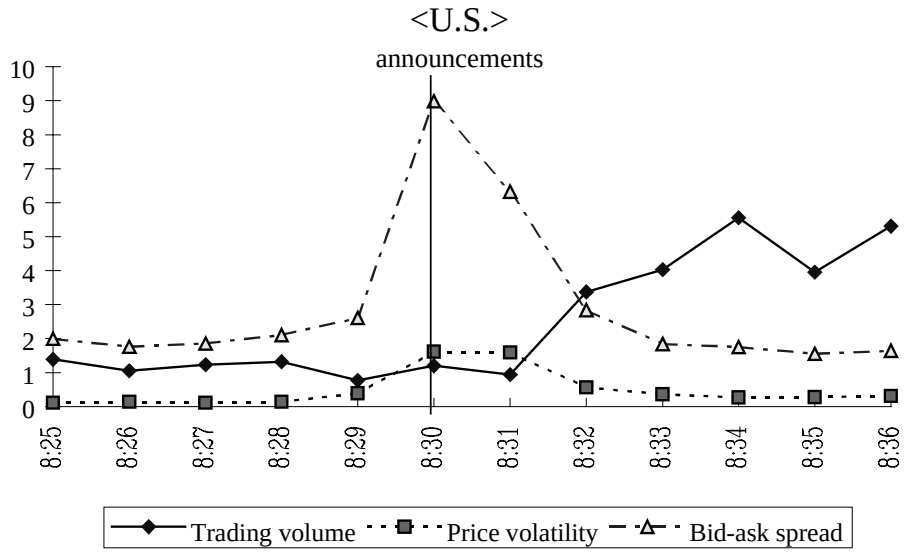


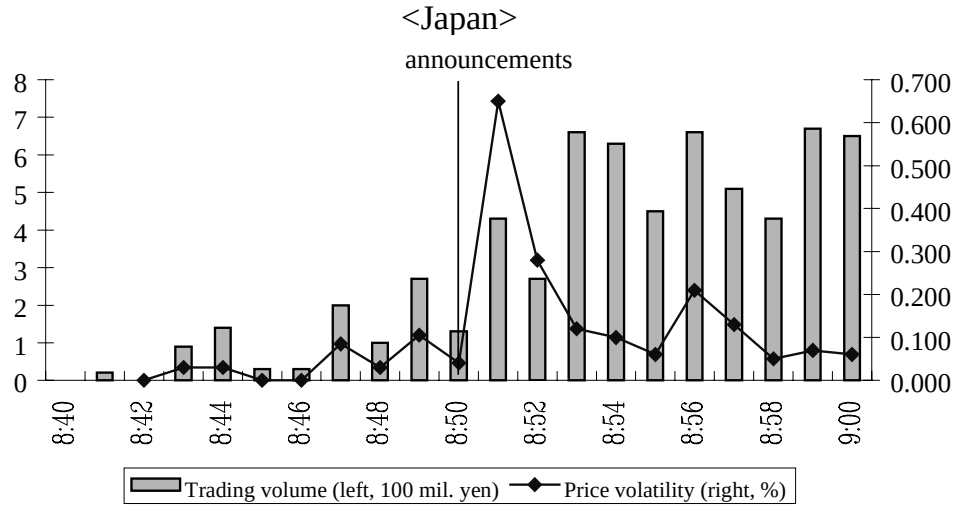
Source: Scalia [1997b]

Notes: The panel shows estimated spread in interdealer trading for benchmark 10 year bonds (BTPs) from January to June, 1993. The spread is measured as a percentage of bond prices. Announcement days are those days when U.S. macroeconomic announcements are made at 14:30 Italian time (8:30 NY time). Separate data are not available after 14:30.

Graph 5

Price Discovery Process Around Statistical Announcements





<U.S.> Source: The author made these graphs using the data in Fleming and Remolona [1997a]

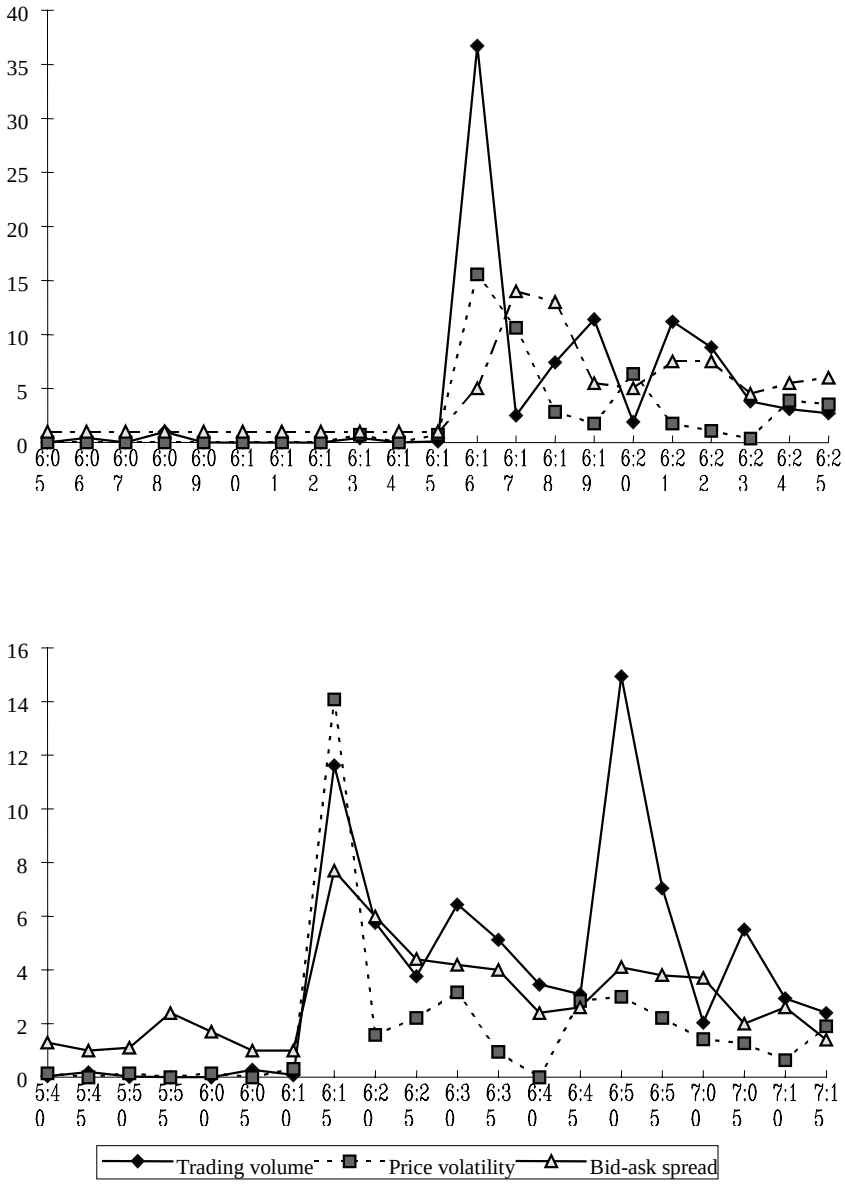
Notes: The graph shows mean trading volume (tens of millions U.S. dollars), standard deviation of log price changes (actual standard deviation times 1,000), and mean bid-ask spread (ten thousandth of face value) for announcement days for the on-the-run 5-year Treasury note. Announcement days are defined as days with at least one of the following announcements: Consumer Price Index, Employment, Producer Price Index, all of whish are announced at 8:30 a.m. The sample period is from August 23, 1993 to August 19, 1994 (250 trading days). The times shown are interval starting times. The upper panel shows the data for each 1-minute segment, and the lower panel shows each 5-minute segment before 8:45 and 15-minute segment after 9:00.

<Japan> Source: Author's calculation.

Notes: The graph shows trading volume and price volatility at around 8:50 when 5 statistics including Tankan and money supply are released. The sample period is from July 1, 1996 to August 29, 1997. Trading volume is the 5-minute average volume of benchmark 10-year bonds through the largest interdealer broker. Price volatility is the standard deviation of log yield changes for the same issue.

Graph 6

Price Discovery Around Policy Rate Changes in Japan



Source: Author's calculations.

Notes: The graph shows trading volume (billion yen), standard deviation of price changes (actual standard deviation times 1,000), and mean bid-ask spread (one-ten-thousandth of notional face value) for the 10-year futures contract on Japanese government bonds traded on the LIFFE. The data are for September 9, 1998, when the Bank of Japan announced that it would cut its policy rate. At 6:06 p.m. (Tokyo time), the Bank of Japan revealed that it would announce the results of its Policy Board Meeting at 6:15 p.m. At 6:15, the Bank's decision to lower the policy rate was posted on information vendor screens. At 6:16, details of the change, i.e., to lower its policy target rate (overnight call rate) from "just below 0.5%" to "0.25%", was posted on the screens. The times shown are interval starting times. The upper panel shows data for each 1-minute segment, and the lower panel shows each 5-minute segment, converted to a per-minute basis.