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Impact of US Macroeconomic News Announcements on Intraday Causalities on Selected European Stock Markets

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Abstract
In this paper we examine the impact of US macroeconomic news announcements on the relationships between returns, volatility and turnover on three European stock markets operating in Frankfurt, Vienna and Warsaw. The empirical analysis in periods with and without important publicly available macroeconomic news is based on intraday data of the main indices of these stock markets, namely DAX, ATX and WIG20. Announcements of important publicly available macroeconomic news essentially increase the number of causal relationships on the markets and between them. Granger causality tests confirm the dominant role of the Frankfurt Stock Exchange. Causality running from DAX returns to returns of ATX and WIG20 is statistically significant irrespective of the time of day and the presence of important macroeconomic news announcements. The only visible feedback runs between WIG20- and DAX-related variables. We also find that most of the causal relationships between the stock exchanges in Warsaw and Vienna are implied by data from the stock exchange in Frankfurt.

1. Introduction

In the theory and practice of financial markets, the view that stock prices reflect investors' expectations on the future performance of companies is widely accepted. These expectations are based on available information about companies. After the arrival of important new information, investors adjust their previous expectations. This process of adjustment is the main source of price movements. Investors usually do not interpret new information in the same way. Therefore, prices may remain unchanged even though new information is revealed to the market and transactions are made. In this case, new information is reflected in trading volume, as the latter sums investors' activity in response to news. In contrast to stock prices, a change in investors' expectations always increases trading volume. Additionally, the discrepancy between investors' reactions to new information is measured by stock price volatility.

Observation and analysis of the joint dynamics of stock prices, volatility and trading volume improve the understanding of information flow and the structure of a given stock market, while also showing the ways through which new information is transmitted between different groups of investors on the market and even between different markets. Transmission of information between markets is especially important when one wants to describe the degree of development of a market or the rationality of its participants.

There are two main conjectures about the way in which new information impacts the dynamic relationships between the variables that describe stock prices. These are the *Sequential Information Arrival Hypothesis* (SIAH) from Copeland (1976) and the *Mixture of Distribution Hypothesis* (MDH) from Clark (1973). Each of them implies the creation of different kinds of relationships after the arrival of new information. The study by Copeland (1976) assumes that not all traders receive new information at exactly the same time but that they receive it sequentially. First, new information is perceived by a group of well-informed investors. As these informed traders change their trading positions and execute transactions, the new information is transmitted to other traders (uninformed or noise traders) who may notice changes in stock prices or trading activity. In consequence, the reaction of these investors also impacts prices and volume and, in turn, transmits information further. The reaction of each group of investors to new information leads to an incomplete equilibrium. The final market equilibrium is reached when all the traders have obtained information and have made a trading decision based on it. Thus, the SIAH implies lead-lag relationships between prices, trading volume and volatility resulting from responses of different groups of investors to new information. The MDH, on the other hand, assumes that new information is received by all investors at the same time. Thus, in the MDH, the shift towards a new equilibrium is immediate and partial equilibriums, as in the Sequential Information Model, never take place. The MDH implies a positive contemporaneous link between trading volume and price volatility. This relationship is a function of a mixing variable defined in the financial literature as the *rate of information flow*.

Investors usually trade even in the absence of important news. This phenomenon partly contradicts investors' rationality and is explained by different behavioral models, for example the overconfidence and biased self-attribution model (Daniel *et al.*, 1998). Overestimation of private information leads to causal relationships between trading volume and volatility in periods without publicly available news. However, as mentioned by Darrat *et al.* (2007), under the assumption of investors' rationality two kinds of causal relationships may be observed when no publicly available news is released. There is a negative causality running from trading volume to volatility and a positive causality from volatility to trading volume.

The aim of this paper is to analyze the impact of important publicly available news[1] on the information flow on and between the three European stock markets in Frankfurt, Vienna and Warsaw. An analysis of the causal relationships between returns, volatility and trading volume on a given stock market in the presence of publicly available macroeconomic news will supply evidence supporting one of the information-flow hypotheses described above. Analogous analysis performed when no such news is released could help in describing investors' rationality on a given market. On the other hand, analysis of cross-country causalities characterizes the information flow between stock markets and answers the question of which market is the main one generating signals to investors on the other stock markets. Additionally, the latter shows how signals are transmitted between different stock markets. Finally, a comparison of results obtained for periods with and without macroeconomic news announce-

[1] In this paper, we consider announcements of several US macroeconomic indicators to be important publicly available news.

ments reveals how publication of important macroeconomic data affects these cross-country relationships.

The stock markets under study differ considerably. The capitalization of the Deutsche Börse (Frankfurt Stock Exchange, FSE) is about ten times greater than that of the Warsaw Stock Exchange (WSE), while WSE capitalization is about twice as much as that of the Wiener Börse (Vienna Stock Exchange, VSE).[2] However, there are also similarities between the VSE and WSE. The main indices of both markets, the ATX and WIG20, respectively, cover a similar period. The ATX index has been quoted since January 2, 1991, while the WIG20 index has been published since April 16, 1994. Additionally, the VSE and WSE are among the largest stock markets in Central and Eastern Europe. In fact, in recent years the VSE and WSE have been competing with each other in the CEE region. On the other hand, the VSE and FSE are developed markets, while the WSE is still seen as an emerging market. In addition, Germany is the most important trading partner for the Austrian and Polish economies. Therefore, it seems interesting to investigate how these similarities and differences are reflected in intraday causalities.

The analysis of causalities between different characteristics of stock prices based on high frequency data allows a comparison of the nature of the process of information flow on such different markets. Another interesting research question concerns the impact of a large stock market (FSE) on information flow on the two smaller neighboring markets.

The application of US macroeconomic news announcements as a proxy for important publicly available news is motivated by the very strong and immediate reaction of European stock markets to US macroeconomic news announcements (Harju and Hussain, 2011; Gurgul and Wójtowicz, 2014, 2015). This type of reaction is even stronger than the reaction to European or domestic macroeconomic news announcements (Nikkinen and Sahlström, 2004). We discuss this issue more deeply in Section 3.

This paper contributes to the existing literature in several ways. It examines not only the dynamic relationships between intraday returns, volatility and trading volume on these European markets, but also deals with the impact of US macroeconomic news announcements on these relationships. The application of intraday data gives new insight into the relationships between these markets, which cannot be achieved on the basis of the daily data that was usually applied in previous research. This is particularly important when we take into account the (very high) speed of the reaction of stock markets to important publicly available news announcements (Gurgul and Wójtowicz, 2014; Dimpfl, 2011).

The rest of the paper is organized as follows: In Section 2, we briefly review the literature concerning the relationships between information arrival, returns, volatility and trading volume with particular interest in studies dedicated to the stock markets under study. In Section 3 we present and analyze in detail the data that we use in the empirical study. Section 4 contains the main empirical findings regarding Granger causality. Section 5 concludes the paper with a brief summary.

[2] At the end of September 2014, the capitalization of the Deutsche Börse was at the level of EUR 1,358,619 million compared to EUR 154,382 million of capitalization of the WSE and EUR 81,221 million capitalization of the VSE. (Source: Federation of European Securities Exchanges, www.fese.eu)

2. Literature Review

This review of the literature is divided into two subsections. In the first one, general results on causalities between the most important financial variables are presented. The second subsection is more specific and focuses on the causal links and impact of US macroeconomic news announcements.

2.1 Relationships between Prices, Trading Volume and Volatility

One of the most common approaches in research into return-volatility-volume interrelationships is the concept of *Granger causality* (Granger, 1969). This can be understood as a special kind of conditional dependence. Applying linear and non-linear Granger causality tests to daily Dow Jones returns and percentage changes in NYSE trading volume, Hiemstra and Jones (1994) supply evidence of bidirectional nonlinear causality between returns and trading volume. These results are in contrast to the empirical work of Gallant *et al.* (1992) based on daily S&P 500 index returns and NYSE trading volume. Gallant *et al.* (1992) show strong nonlinear effects of lagged stock returns on current trading volume, but only a weak nonlinear impact of lagged trading volume on current stock returns. The above-mentioned studies reflecting the domestic relationships in a dynamic (causal) context between trading volume and stock returns are supplemented by Lee and Rui (2002), who examine dynamic relationships between the three largest stock markets, namely those of the US, UK and Japan. The main result found by the authors is that US financial market variables, in particular trading volume, influence UK and Japanese stock-exchange-related variables.

Causalities between different characteristics of stock prices have also been investigated in the case of emerging markets in the CEE region. For example, Gurgul and Majdosz (2005) show evidence of significant bi-directional linear causality between daily stock returns and trading volume on the Warsaw Stock Exchange (WSE). They also prove significant unidirectional linear causality running from trading volume to return volatility. The robustness of these results is verified by taking into account calendar effects and repeating the analysis in various sub-samples. Gurgul and Majdosz (2005) also indicate that U.S. returns (volatility) have predictive power for Polish trading volume. The same is also true for returns (volatility) of the German stock market. On the other hand, the authors do not find evidence of a similar link in the case of the Austrian stock market.

In recent years, causality relationships have been investigated also on the basis of intraday data. Due to the development of financial markets, dependencies between high frequency data are much more important and give better insight into information flow than analyses based only on daily data. Rossi and de Magistris (2010) investigate the relationship between the realized volatility and trading volume of four stocks listed on the NYSE using intraday data. They show that volume and volatility exhibit long memory but are not fractionally cointegrated. These findings do not support the MDH in the version of Bollerslev and Jubinski (1999). However, the application of fractionally integrated VAR models shows that filtered log volume has a positive effect on current filtered log volatility.

Using intraday data of 30 stocks listed in the DJIA, Darrat *et al.* (2003) indicate that high trading volume causes high return volatility in line with the SIAH but contrary to the MDH. The pattern (contemporaneous or dynamic) of the dissemination of publicly available news to market participants plays a crucial role in the assessment of the validity of the MDH versus the SIAH for particular stock markets. Macroeconomic data announcements can be seen as such important news when the reaction of whole stock markets is analyzed.

The methods applied by Darrat *et al.* (2003) are not able to distinguish between the SIAH and other plausible explanations of the observed causal relationships, such as the overconfidence hypothesis. The distinction between these two alternative views is possible after taking into account the information on the time of the day when the publicly available news appears. In the absence of public signals, rational investors would not change their positions. Thus, under the rationality assumption, no causal link between volume and volatility is expected. On the other hand, in the behavioral approach, investors do not require the presence of new information to trade. Even without public signals, quasi-rational investors may still overreact to their own (private) signals and execute trading.

This interesting direction of research is continued by Darrat *et al.* (2007), who reexamine the lead-lag relationship between trading volume and the volatility of large and small stocks from the NYSE in periods both with and without identifiable publicly available news. This contribution refers also to the works of Fama (1998), Pritamani and Singal (2001) and Chan (2003), who propose a similar procedure, albeit in different contexts.[3] Darrat *et al.* (2007) uncover evidence supporting the SIAH during periods with publicly available news. However, they also demonstrate that trading volume Granger-causes return volatility even in periods without publicly available news. Moreover, return volatility is higher in the periods with publicly available news, while trading volume becomes significantly higher in the no-news periods. In addition, all these results are invariant with respect to different times of day. Some of the results of Darrat *et al.* (2007) support the self-attribution model of Daniel *et al.* (1998), suggesting that investors are overconfident.

2.2 US Macroeconomic News Announcements and Causalities between European Stock Markets

There are several papers analyzing the impact of US macroeconomic news on European stock markets (e.g. Nikkinen and Sahlström, 2004; Nikkinen *et al.*, 2006; Hanousek *et al.*, 2009; Harju and Hussain, 2011; Gurgul and Wójtowicz, 2014, 2015). However, their conclusions are sometimes divergent.

Nikkinen and Sahlström (2004) show that the implied volatility on the German and Finnish equity markets reacts significantly only to US announcements regarding the unemployment rate and PPI. Moreover, both markets are hardly influenced by announcements of domestic macroeconomic data. Nikkinen *et al.* (2006) show that announcements of some US macroeconomic indicators significantly increase volatility on developed European stock markets (including Austria). On the other

[3] Taking into account a subset of stocks from the time period 1990–1992, Pritamani and Singal (2001) analyzed return predictability following announcements and large price changes. Chan (2003) collected news headlines for a subset of Center for Research in Security Prices (CRSP) stocks over the period 1980–2000. He compared monthly returns following announcements of publicly available macroeconomic news and returns after similar price movements in the absence of publicly available macroeconomic news. For more details, see Pritamani and Singal (2001) and Chan (2003).

hand, the reaction of CEE economies in transition (including the Czech Republic, Hungary, Poland, Russia and Slovakia) is insignificant. This suggests a substantial difference in the reaction to US macroeconomic news between developed and emerging markets in Europe. As shown by Singh *et al.* (2013), announcements of US macroeconomic data more frequently impact volatility than returns on developed European markets.[4] Also, the strong impact of US news announcements on volatility on emerging markets (including Poland, Russia and Turkey) is confirmed by Cakan *et al.* (2015). On the other hand, Gümüş *et al.* (2011) show that US data announcements do not impact the Istanbul Stock Exchange.

Using high frequency data, Harju and Hussain (2011) find that US macroeconomic news announcements induce an immediate and significant reaction in the intraday volatility and returns of the CAC40, DAX30, FTSE100 and SMI. The reaction of the Frankfurt Stock Exchange is also examined by Dimpfl (2011), who shows that one-minute returns of the DAX react immediately after the news release.

The reaction of emerging markets in the Czech Republic, Hungary and Poland to various macroeconomic news announcements is examined by Hanousek *et al.* (2009), who show that the strongest reaction of five-minute returns is observed on the stock market in Prague. Investors in Budapest react significantly only to negative news, while the Warsaw Stock Exchange seems to be uninfluenced by US macroeconomic news. Additionally, Hanousek *et al.* (2009) prove significant spillover effects on the emerging markets under study. Their main indices influence each other, but they are also significantly influenced by previous returns of the DAX. The impact of the Frankfurt Stock Exchange (via the DAX) is even stronger than the impact of any of the emerging markets. Significant causality from the FSE to the stock markets in Prague and Warsaw is also evidenced by Černý and Koblas (2005). The important role of developed European markets for the CEE emerging markets in Budapest, Prague and Warsaw is also indicated by Égert and Kočenda (2007), who show significant causalities between the returns of the CEE markets and causalities running from developed to emerging European stock markets. The opposite causalities running from stock-related variables in Eastern European countries to Western countries are insignificant. There is a similar pattern for volatilities with the exception that volatility in Budapest and Warsaw is significant for the prediction of volatilities on the stock markets in Frankfurt and London. A deeper analysis of intraday relationships between CEE markets is carried out by Égert and Kočenda (2011), who find very little positive time-varying correlations among the returns of the BUX, PX50 and WIG20. In addition, correlations between these markets and Western European stock markets are very weak.

The reaction of the Polish stock market to US announcements is also examined in detail by Gurgul and Wójtowicz (2014). On the basis of intraday data, they show that the WIG20 (the main index of the Warsaw Stock Exchange) reacts to unexpected news from the US economy in the first minutes after a news release. Significant reactions are induced by announcements regarding industrial production, durable goods orders, retail sales and nonfarm payrolls. The last of these produces the strongest reaction.

[4] For example, they influence volatility on stock markets in UK, France Germany and Italy, while returns are affected only in Germany.

3. The Dataset

3.1 Periods with and without Information

In order to describe the information flow on the stock markets under study and between them, we analyze causal relationships in the presence of important macroeconomic news and in periods without such news. Due to globalization, stock markets are continuously deluged with different information from all around the world. Hence, it is very difficult to isolate periods without important information. However, we decided to choose a kind of worldwide news that is very important to investors on all three stock markets under study. Among possible candidates, macroeconomic news announcements from the US economy would seem to be a reasonable choice. The previous literature has proved that US macroeconomic news announcements significantly impact European stock markets.[5] Moreover, the impact of US announcements is often even stronger than the impact of domestic macroeconomic data announcements. We are aware that the stock markets under study are influenced by other important news (domestic announcements or news about the eurozone economy) that may bias the results of this paper somewhat. However, previous studies about the importance of US macroeconomic news suggest that this bias should be negligible. In addition, in light of the literature reviewed, no other type of publicly available information has been proven to have such a strong impact on European stock markets as US macroeconomic news announcements.

Based on these results, we define a *trading session with information* as a trading session when at least one of the following US macroeconomic indicators was announced: the Consumer Price Index, the Producer Price Index, industrial production, retail sales, durable goods orders, nonfarm payrolls, existing home sales, housing starts, new home sales and consumer confidence. All these macroeconomic indicators are released monthly on different days of the month between 14:00 CET (Central European Time) and 16:00 CET.[6] This ensures that the impact of these announcements can be directly observed in stock prices, particularly in the values of all the indices. In this paper we apply data from 111 trading days between March 22, 2013 and September 5, 2013. In our sample there are 48 days with US macroeconomic news announcements and 63 sessions without announcements of the above-mentioned macroeconomic indicators. We also consider the impact of good or bad news on causality relationships between the markets. We define good and bad news by means of a comparison of the announced value of the indicator with the consensus published by Bloomberg. News is good when the announced value is greater than the consensus (except information about inflation, where we use the opposite definition). Conversely, an announced value below expectations is seen as bad news. Among 48 days with news announcements, there are 13 days with bad news and 19 days with good news. In the case of the other days, the announced value was as expected or there were simultaneous announcements of good and bad news.

The main reason for the restriction of the sample to these particular months in 2013 is the availability of intraday data for all three stock markets under study.

[5] See, for example, Andersen *et al.* (2007), Nikkinen and Sahlström (2004), Nikkinen *et al.* (2006), Harju and Hussain (2011), and Gurgul and Wójtowicz (2014).

[6] Henceforth we will omit "CET".

Fortunately, within this time frame the situation on all three selected stock markets was rather stable (slow and permanent increase of the DAX, ATX and WIG20) in contrast to the situation following the outbreak of the financial crisis in 2008. It is worth mentioning that in 2014 the authorities in Poland conducted (to a large extent) the nationalization of private pension funds (OFEs). This decision has induced an ongoing huge negative effect on the Warsaw Stock Exchange since OFEs were the main domestic institutional investors on the Warsaw Stock Exchange.

3.2 Returns, Volatility and Turnover

To perform the empirical analysis, we apply intraday data describing stock exchanges in Frankfurt, Vienna and Warsaw in the period from March 22, 2013 to September 5, 2013.

The data on the German, Austrian and Polish stock markets comes from the Bloomberg, Vienna Stock Exchange and Warsaw Stock Exchange databases, respectively. We consider five-minute log returns of the markets' main indices: DAX (FSE), ATX (VSE) and WIG20 (WSE). Squared returns are proxies for return volatility.[7] The values of the indices under study are based on the prices of stocks of the largest firms quoted on each market. The stocks of these "blue chips" are among the most liquid assets and attract investors' and analysts' attention. Any important information that reaches the market and triggers a reaction by investors is immediately reflected in the prices of the "blue chips" and, in consequence, in the indices. Hence, the values of indices under study properly reflect all the information available at any given moment in time.

In business practice and in the economic literature, several measures of investor trading activity are used. Among the most frequently applied measures, one should list trading volume (the number of shares traded) and turnover (the total value of shares traded).[8] In general, the number of shares traded seems a good measure of investors' activity in the case of a single security. Market indices, however, contain stocks with considerably different prices and different total numbers of shares traded. Thus, trading volume computed for an overall index may be dominated by the trading volume of a single firm. Therefore, to describe investors' activity on the stock markets we apply turnover, which in this case seems to be a more robust measure. More precisely, we compute the difference between the total index turnover at the end and at the beginning of each five-minute interval. Such a quantity describes the value of shares from a given index traded during a given five-minute interval. This five-minute turnover, however, is highly skewed. To deal with this issue in the further analysis, we apply natural logarithms of five-minute turnover.

The three stock markets were open at different hours. In the period under study, continuous trading started at 8:55 on the VSE and at 9:00 on both the FSE and WSE. It ended at 17:20 (WSE), 17:30 (FSE) and 17:35 (VSE). Moreover, on the FSE there is an intraday auction from 13:00 to 13:02. On the VSE the intraday auction lasts from 12:00 to 12:07:30 on settlement days and from 12:00 to 12:04 on non-settlement days of the derivatives market. Causal relationships, however, must be

[7] Since we examine causalities between returns and volatility, we do not use conditional volatility measures based on GARCH-type models, as they are calculated on the basis of historical values of returns.
[8] See, for example, Bollerslev and Jubinski (1999), Lobato and Velasco (2000).

analyzed only in the periods when all three markets are open and may influence each other. We restrict our study to even shorter periods because of periodicity in the intraday volatility of European stock indices. Periodic patterns (U-shaped or J-shaped) in absolute or squared returns are a well-known feature observed on a variety of stock markets.[9] Due to increased volatility at the beginning and at the end of trading sessions, we study causal relationships between intraday returns, volatility and the turnover of the DAX, ATX and WIG20 on the basis of data between 9:20 and 16:45. Due to the intraday auctions, we use two sub-periods during trading days. The first sub-period is from 9:20 to 11:45 and the second is from 13:25 to 16:45. Both sub-periods start at least 15 minutes after the beginning of continuous trading on each of the markets and end at least 30 minutes before the end of trading sessions. To avoid potential problems with modeling the increased volatility just before or just after the intraday auctions on the Frankfurt or Vienna Stock Exchanges, we also apply 15-minute gaps before and after the intraday auctions.

The first period (9:20–11:45) may be referred to as the *morning period,* when there are no US news announcements, whereas in the second period (13:25–16:45)—the *afternoon period*—US stock markets are open and US macroeconomic news is announced. The analysis of the relationships between returns, volatility and turnover in these two periods on days when US macroeconomic news is announced and on days without such announcements allows us to describe the impact of important publicly available news on causality.

The restriction of the analysis to these periods does not completely remove the periodic pattern from the volatility series. The top panels of *Figure 1* present cross-sectional averages of the absolute values of the five-minute returns of the DAX, ATX and WIG20 in both periods.[10] One can see that there are differences between morning and afternoon trading, since a decreasing trend in volatility in the morning period and increased volatility in the afternoon period are clearly visible. A similar pattern is observed in the bottom panels of *Figure 1* in the case of average five-minute turnover. It is worth noting that the right panels of *Figure 1* also confirm the strong impact of news about the US economy on European stock markets. The average five-minute absolute returns presented in the top right panel increase at about 14:30 and at about 16:00 when US macroeconomic news is usually announced. These strong reactions are confirmed by changes in turnover, particularly in the turnover of the DAX, which also increases at about 15:30 when the New York Stock Exchange opens.

In order to eliminate the impact of periodicity from the volatility and turnover time series under study, we divide each five-minute return by the appropriate cross-sectional standard deviation in the given five-minute interval.[11] Next, on the basis of the modified returns series, volatility is computed once again as squared returns. Similarly, any seasonal pattern is removed from the five-minute turnover series by subtracting the cross-sectional averages in each five-minute interval.[12] Further

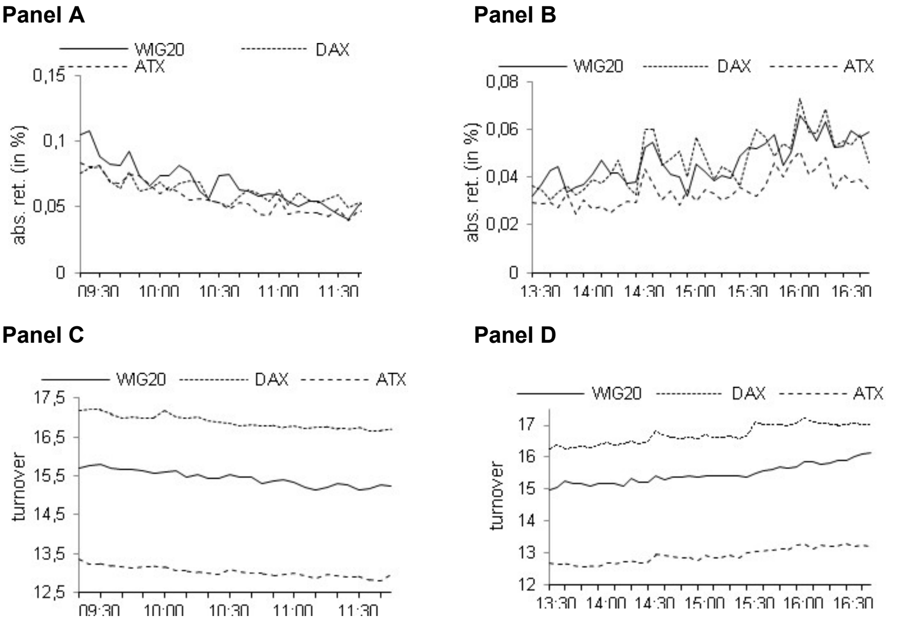
[9] See, for example, Harris (1986), Harju and Hussain (2011).

[10] At given time t we compute the average of the absolute values of all the returns observed at that time of day in the whole sample.

[11] See, for example, Bauwens *et al.* (2005).

[12] Henceforth, we refer to these corrected variables as volatility and turnover, respectively.

Figure 1 Intraday Periodicity in Volatility and Turnover on the Three Stock Markets



Notes: Averages of the absolute values of five-minute returns of the WIG20, DAX and ATX (in %) in the morning period (Panel A) and in the afternoon period (Panel B). Averages of five-minute turnover of the WIG20, DAX and ATX in the morning period (Panel C) and in the afternoon period (Panel D).

analysis shows no visible differences between volatility and trading activity in each of the periods when US macroeconomic news announcements are taken into account. The boxplots in *Figure 2* are very similar regardless of the presence of important public news.

Following the suggestions of the previous literature,[13] we expect that the volatility and turnover series may exhibit long memory. The existence of long memory implies the significance of the autocorrelation function even for very large lags. More precisely, a covariance stationary stochastic process exhibits long memory with memory parameter d when its spectral density function $f(\lambda)$ satisfies the condition

$$f(\lambda) \sim c\lambda^{-2d} \text{ when } \lambda \to 0^{+}$$

where c is a finite positive constant and the symbol "~" means that the ratio of the left- and right-hand sides tends to one. The latter is equivalent to the condition that the autocorrelation function decays at a hyperbolic rate, i.e.[14]

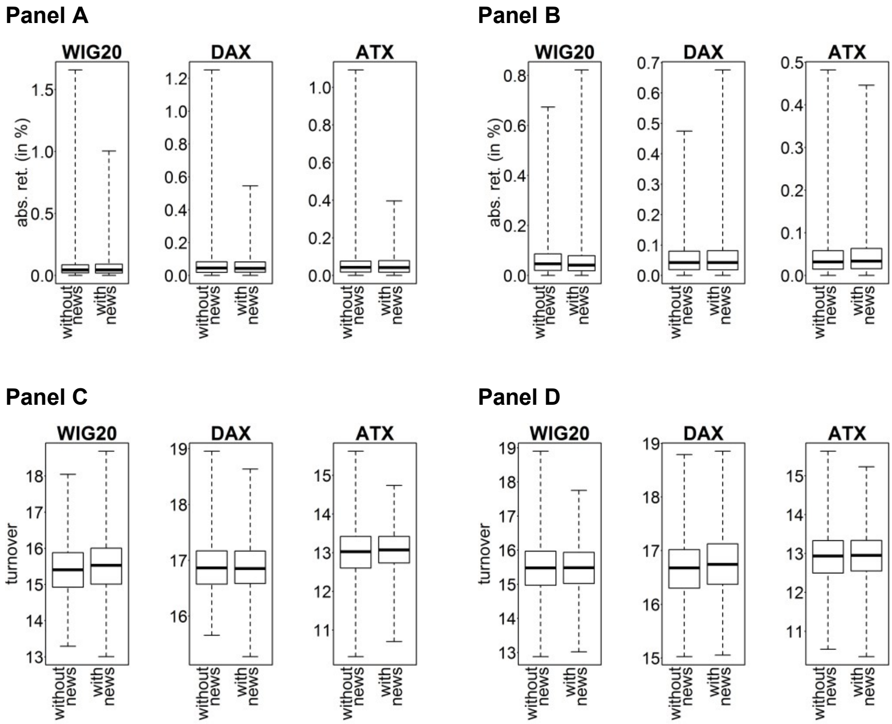
$$\rho_k \sim c_\rho k^{2d-1} \text{ as } k \to +\infty$$

We estimate the long memory parameter d by means of the semiparametric method of Geweke and Porter-Hudak (1983) with bandwidth parameter m equal to

[13] See, for example, Bollerslev and Jubinski (1999), Gurgul and Wójtowicz (2006), Fleming and Kirby (2011) and Rossi and de Magistris (2010).

[14] Comp. Granger and Joyeux (1980).

Figure 2 Descriptive Statistics of Intraday Volatility and Turnover on the Three Stock Markets



Notes: Boxplots of the absolute values of five-minute returns of the WIG20, DAX and ATX (in %) in the morning period (Panel A) and in the afternoon period (Panel B). Boxplots of five-minute turnover of the WIG20, DAX and ATX in the morning period (Panel C) and in the afternoon period (Panel D).

$T^{0.65}$, where T is the number of observations. The long memory estimator $\hat{d}_{GPH}$ of Geweke and Porter-Hudak (1983) is consistent and has an asymptotically normal limit distribution. *Table 1* presents estimates of the long memory parameters of the volatility and turnover time series estimated in each period separately. All long memory parameters are significant at least at the 1% level and indicate stationarity of the time series under study.

The results presented in *Table 1* indicate the existence of significant long memory in each volatility and turnover time series. In line with previous studies, the long memory parameter for turnover is greater than that for volatility. Because long memory as well as strong and slowly decaying autocorrelations may heavily impact the results of causality tests, we remove them by fractional differencing. The causality tests presented in Section 4 are performed on the basis of filtered volatility and turnover series.

4. Granger Causality

The time series of five-minute returns, volatility and turnover of the DAX, WIG20 and ATX described in the previous section are the basis for an analysis

Table 1 Long Memory Estimates of Volatility and Turnover

	9:20–16:45		9:20–11:45		13:25–16:45	
	Volatility	Turnover	Volatility	Turnover	Volatility	Turnover
ATX	0.396	0.532	0.395	0.526	0.349	0.531
DAX	0.198	0.480	0.118	0.458	0.272	0.557
WIG20	0.134	0.502	0.101	0.479	0.208	0.524

of Granger causality on each of the three European stock markets as well as between them. The concept of Granger causality is well known in the economic literature and thus we will not introduce this idea in detail. Instead of focusing on alternative concepts, we decided to use Granger causality mainly due to its popularity in previous research focused on stock market causal links (e.g. Darrat *et al.*, 2003; Darrat *et al.*, 2007). This way, the methodology used in our paper is generally comparable to that of most of the previous studies, so that the outcomes of our research may be readily compared with the existing state of the art. The main part of the analysis of causal relationships between returns, return volatility and the turnover of the DAX, ATX and WIG20 is performed by means of pair-wise Granger causality tests. For each pair of variables, we estimate bivariate VAR models with $k = 1,2,\ldots,10$ lags and compute Ljung-Box statistics to verify the randomness of residuals. The causality test is performed on the basis of the model with the lowest number of lags ensuring insignificant autocorrelation in residuals. When no such model exists for a given pair of variables, we use the VAR model with five lags and with heteroskedasticity and autocorrelation consistent (HAC) estimators of the covariance matrix.[15] Additionally, to avoid the possible problem of over-rejection due to the large size of the data in the causality tests (see, for example Darrat, *et al.*, 2007), in the Granger causality test we use only the 1% significance level.

4.1 Days without US Macroeconomic News Announcements

First, we analyze causalities on days without important US macroeconomic news announcements. During these days, it is not precluded that other information (domestic or Europe-wide) reaches the markets. However, if there were no arrival of new important public information in this period, all trading would be based on private information. Thus, the analysis of domestic causalities on days without US macroeconomic news announcements may help to describe the rationality of investors on each of the markets. The results of this part of the causality analysis are presented in *Table 2*.

The results presented in *Table 2* indicate that in the period from 9:20 to 11:45 there are six significant domestic causal links running from returns to volatility (on the WSE and VSE), from returns to turnover (on the FSE), from volatility to turnover (on the FES and VSE) and from volatility to returns (on the VSE). The sign of the relationships between volatility and trading activity is important when describing the rationality of investors. Both causalities running from returns to volatility are positive. Such a positive causality is one of the possible volume-volatility relation-

[15] See, for example, Andrews (1991) and Zeilies (2004).

Table 2 Causality Analysis on Days without US Macroeconomic News Announcements Period from 9:20 to 11:45 CET

Cause		WIG20			DAX			ATX		
		R_t	R_t^2	V_t	R_t	R_t^2	V_t	R_t	R_t^2	V_t
WIG20	R_t		**9.25**$^{+}$	0.90	0.72	0.84	1.25	**7.97**$^{+a}$	1.77	**7.98**$^{-a,c}$
	R_t^2	0.14		2.20	5.91	0.66	0.20	0.31	0.08	0.70
	V_t		0.10		0.92	0.61	0.01	0.40	0.35	1.60
DAX	R_t	**53.25**$^{+}$	1.08	0.51		2.28	**20.08**$^{-}$	**91.96**$^{+}$	4.24	**4.66**$^{-b,c}$
	R_t^2	4.37	1.46	3.23	3.15		**81.72**$^{+}$	5.77	15.37	**12.62**$^{+}$
	V_t	0.46	1.96	2.29	2.26	0.14			1.60	3.38
ATX	R_t	**8.32**$^{+a}$	1.83	0.71	0.19	0.98	0.02		**8.58**$^{-}$	3.85
	R_t^2	2.29	1.75	0.53	4.00	5.10	2.04	**12.76**$^{+}$		**5.68**$^{+b}$
	V_t	0.01	2.64	0.53	0.88	0.42	0.36	1.26	3.38	

Notes: The table presents F statistics in Granger causality tests between returns (R_t), volatility (R_t^2) and turnover (V_t) of the DAX, WIG20 and ATX. Bold font is used to mark results significant at the 1% level. +/- indicates positive/negative sign of causality (positive/negative value of the sum of coefficients on respective lags in the VAR model).

a, b, c—indicate that a relationship becomes insignificant when lagged DAX returns (a), volatility (b) or turnover (c) are included in a VAR model.

ships taking place under the assumption of investors' rationality in the absence of important publicly available news. This kind of causality can occur when volatility declines as a result of the return of incorrect prices to their expected intrinsic values. Correctly priced assets cease to be attractive for rational investors and trading volume also declines. Under the assumption of investors' rationality, this positive relationship should be accompanied by negative causality running from turnover to volatility. However, from *Table 2* it follows that for the DAX and ATX these relationships are insignificant. Nevertheless, these results do not contradict the rationality of investors on stock markets.

Other interesting relationships are the bidirectional causalities between returns and volatility on the VSE. The causality running from returns to volatility is negative, while the opposite relationship is positive. The latter indicates that changes in the ATX are suppressed, because increased returns are followed by decreased volatility, which, in turn, causes returns to decrease back to zero. On the other hand, negative returns increase volatility. However, increased volatility increases returns back to zero. The impact of the returns of the WIG20 on volatility is quite different—the causality is positive and positive changes in the WIG20 increase its volatility. These results uncover difference in the behavior of investors on the CEE markets under study.

When we analyze cross-country causalities, two important observations can be made. First, the majority of causalities lead to ATX-related variables. The main index of the VSE is influenced by WIG20 returns and by the returns and volatility of the DAX. On the other hand, only two causal relationships leading to WIG20 returns are observed: positive causalities running from the returns of the ATX and from the returns of the DAX. This means that DAX returns impact the returns of both the WIG20 and ATX, while the returns of the WIG20 and ATX impact each other. This is the second important observation implying that changes in the DAX are the main sources of information for investors on both the VSE and WSE. Moreover, there is no feedback and the DAX is not influenced by information contained in the WIG20 and ATX. This indicates a dominant role of FSE when no important macroeconomic news from the US economy is released. This domination is reinforced when we study Granger causality between the WIG20 and ATX on the basis of trivariate VAR models with historical DAX data as an additional variable. When lagged DAX returns are included in the respective trivariate VAR models, the causalities between the WIG20 and ATX returns become insignificant. This implies that the relationships between the returns of the WIG20 and ATX are somewhat virtual, since they are driven mostly by the impact of DAX returns on both indices. Similarly, causality from WIG20 returns to ATX turnover can be explained by the impact of DAX returns. Finally, there are only three relationships that cannot be explained by any of the DAX variables: causality running from WIG20 returns to WIG20 volatility and bidirectional causality between the returns and volatility of the ATX. This observation suggests that the FSE impacts not only both the WSE and VSE, but also that the relationships between them and both smaller CEE markets do not impact each other. These results are partially in line with the results of Černý and Koblas (2005) and Égert and Kočenda (2007). When only European and Asian markets are open and no important news from the US economy is expected, the reaction of large developed European stock markets, like the FSE, is the main source of information for investors on the CEE markets. The investors simply look at the FSE and mimic the behavior of investors from more developed markets. Hence, returns on the VSE and WSE tend to follow returns on the FSE.

In addition, we may use trivariate VAR models to study the explanatory power of different characteristics of the DAX. For example, when we include lagged values of DAX volatility, the impact of DAX returns on ATX turnover becomes insignificant. This is probably due to the strong impact of DAX volatility on ATX turnover itself, which cannot be weakened either by including DAX returns or DAX turnover.

When we restrict our attention to the period from 13:25 to 16:45 (see *Table 3*), i.e. the period when financial markets in the US are open, the number of significant Granger causalities decreases.

There are four domestic (on the WSE and VSE) and seven cross-country relationships significant at the 1% level. As in the case of the morning session, the DAX is not influenced by the CEE markets. Additionally, there are no significant domestic causalities between DAX characteristics. On the other hand, DAX returns still impact the returns of the WIG20 and ATX. The impact of the stock exchange in Frankfurt also explains domestic causalities observed on the VSE. Lagged DAX returns make causality from ATX volatility to returns insignificant, while DAX turnover has a similar impact on causality from ATX returns to turnover. The latter implies that causalities on the VSE are generated by signals from the much larger FSE. Domestic causalities on the WSE, however, cannot be fully explained in that way. They remain significant even when DAX characteristics are included in the model. Similarly, causality running from WIG20 volatility to ATX volatility is unaffected by the DAX. Therefore, the stock exchange in Vienna seems to be affected by the stock

Table 3 Causality Analysis on Days without US Macroeconomic News Announcements Period from 13:25 to 16:45 CET

Cause		WIG20			DAX			ATX		
		R_t	R_t^2	V_t	R_t	R_t^2	V_t	R_t	R_t^2	V_t
WIG20	R_t		2.12	0.23	0.14	0.19	0.36	1.64	1.21	0.03
	R_t^2	**7.38**$^{-}$		**12.04**$^{+}$	3.56	1.12	0.58	**7.90**$^{-a}$	**7.60**$^{+}$	0.84
	V_t	0.10	1.58			1.79	0.14	0.13	0.91	2.09
DAX	R_t	**29.73**$^{+}$	0.72	0.77		0.99	0.85	**82.03**$^{+}$	0.45	1.54
	R_t^2	0.35	1.07	**4.71**$^{+c}$	0.07		4.49	1.81	2.84	**6.37**$^{+c}$
	V_t	0.45	0.81	0.46	0.77	0.96		0.27	2.89	**4.53**$^{-b}$
ATX	R_t	0.73	1.41	1.08	0.01	1.14	0.63		0.32	**3.82**$^{-c}$
	R_t^2	1.34	1.11	0.66	0.13	3.74	3.05	**7.20**$^{-a,b}$		3.66
	V_t	0.01	1.53	0.09	2.01	1.24	4.50	0.68	0.26	

Notes: The table presents *F* statistics in Granger causality tests between returns (R_t), volatility (R_t^2) and turnover (V_t) of the DAX, WIG20 and ATX. Bold font is used to mark results significant at the 1% level. +/-indicates positive/negative sign of causality (the sign was established on the basis of the sum of coefficients on respective lags in the VAR model).

a, b, c—indicate that a relationship becomes insignificant when lagged DAX returns (a), volatility (b) or turnover (c) are included in a VAR model.

exchanges in Frankfurt and Warsaw, while the WSE seems to be influenced only by the FSE. This is an essential difference between the stock exchanges in Vienna and Warsaw.

4.2 Days with US Macroeconomic News Announcements

When important macroeconomic data from the US economy are expected to be announced, the number of causalities on the FSE, VSE and WSE in the morning period (see *Table 4*) decreases noticeably when compared to the results in *Table 2*.

In this case, only seven relationships are significant (four domestic and three cross-country). Bidirectional causality between returns and volatility is observed on the WSE. The signs of this causal link are similar to the causalities on the VSE reported in *Table 2*: negative causality running from returns to volatility and positive causality in the opposite direction. None of these can be explained by the DAX. On the contrary, positive causality running from ATX volatility to turnover is insignificant when lagged DAX volatility is taken into account in the respective VAR model. There is no visible impact from the VSE or WSE on any other market under study and investors on both markets react to local information or to signals generated on larger markets, like the FSE. As in days without US news announcements, the most significant causalities are those running from DAX returns to the returns of the ATX and WIG20. DAX volatility is also important with respect to the information flow between the stock markets under study, because it indirectly (through DAX turnover) impacts WIG20 turnover. Hence, it can be concluded that when important US macroeconomic news is expected to be announced, investors on the CEE markets still look at the FSE, and DAX returns and volatility are the main

Table 4 Causality Analysis on Days with US Macroeconomic News Announcements Period from 9:20 to 11:45 CET

Cause		WIG20			DAX			ATX		
		R_t	R_t^2	V_t	R_t	R_t^2	V_t	R_t	R_t^2	V_t
WIG20	R_t		**5.79**$^{-}$	0.91	0.25	0.65	0.01	1.77	0.08	0.64
	R_t^2	**7.68**$^{+}$		6.39	0.10	0.91	1.84	0.10	0.03	0.10
	V_t	0.09	2.21		0.06	1.92	6.01	0.19	1.77	1.19
DAX	R_t	**9.93**$^{+}$	1.22	1.39		0.83	3.01	**65.15**$^{+}$	1.47	0.46
	R_t^2	0.38	2.60	3.86	2.94		**7.02**$^{+a}$	0.04	4.70	2.64
	V_t	0.26	0.94	**7.45**$^{+a,b}$	0.35	0.87		0.12	1.81	2.98
ATX	R_t	3.68	0.85	2.51	0.67	2.43	3.99		0.03	0.47
	R_t^2	0.68	0.35	0.70	0.32	0.05	0.61	5.61		**3.96**$^{+b,c}$
	V_t	0.94	0.92	1.02	0.35	0.05	0.02	0.37	0.10	

Notes: The table presents F statistics in Granger causality tests between returns (R_t), volatility (R_t^2) and turnover (V_t) of the DAX, WIG20 and ATX. Bold font is used to mark results significant at the 1% level. +/- indicates positive/negative sign of causality (the sign was established on the basis of the sum of coefficients on respective lags in the VAR model).

a, b, c—indicate that a relationship becomes insignificant when lagged DAX returns (a), volatility (b) or turnover (c) are included in a VAR model.

ways that information from the FSE is transmitted to the CEE stock markets. None of the observed domestic relationships contradict investors' rationality on the stock markets under study.

Announcements of US macroeconomic news substantially increase the number of causality relationships on the markets and between them (see *Table 5*).

The first important difference between *Table 5* and the previous tables are the three domestic causalities on the FSE. DAX returns negatively impact both volatility and trading activity. It seems that the negative causality running from DAX returns to DAX volatility may be explained as follows: The US economy grew in 2013 and, in general, investors were optimistic about US macroeconomic data. They expected positive news and, in fact, positive news from the US economy dominated in the period under study. Good news, followed by positive returns, confirmed investors' expectations and reduced their uncertainty. On the other hand, bad news followed by negative returns went against expectations and, therefore, increased the discrepancy in investors' reactions. Thus, it also increased return volatility. Similarly, the negative impact of DAX returns on trading activity is also related to the existence of positive causality from DAX volatility to turnover.

Quite a different reaction of investors to the arrival of US macroeconomic news is observed on the WSE, where bidirectional causalities between WIG20 returns and their volatility are positive. However, domestic causality from returns to volatility is insignificant when DAX returns are taken into account in the respective VAR model. Similarly, the only visible causality on the VSE, i.e. causality running from ATX volatility to turnover, can be explained by the indirect impact of DAX volatility.

Table 5 Causality Analysis on Days with US Macroeconomic News Announcements Period from 13:25 to 16:45 CET

Cause		WIG20			DAX			ATX		
		R_t	R_t^2	V_t	R_t	R_t^2	V_t	R_t	R_t^2	V_t
	R_t		**3.99**$^{+a}$	1.24	0.01	2.49	0.55	2.51	5.68	0.28
WIG20	R_t^2	**3.53**$^{+}$		2.09	**8.50**$^{-}$	**3.12**$^{+a,c}$	**11.62**$^{+b}$	1.52	**32.04**$^{+}$	1.47
	V_t	1.44	1.92		1.32	2.12	1.47	0.25	3.04	2.17
	R_t	**4.27**$^{+}$	**5.16**$^{+}$	2.08		**6.58**$^{-}$	**8.03**$^{-b}$	**37.65**$^{+}$	**7.04**$^{-b,c}$	0.35
DAX	R_t^2	0.83	2.93	2.83	0.17		**26.37**$^{+}$	1.25	**65.86**$^{+}$	**8.39**$^{+}$
	V_t	1.16	2.60	1.66	0.01	1.06		0.50	**8.50**$^{+b}$	2.92
	R_t	0.36	1.12	0.04	0.17	**4.69**$^{-a,c}$	2.10		1.58	0.25
ATX	R_t^2	1.16	2.12	0.04	1.73	1.92	3.35	0.16		**5.94**$^{+b}$
	V_t	0.46	1.24	0.18	0.24	0.43	0.85	1.76	0.87	

Notes: The table presents *F* statistics in Granger causality tests between returns (R_t), volatility (R_t^2) and turnover (V_t) of the DAX, WIG20 and ATX. Bold font is used to mark results significant at the 1% level. +/- indicates positive/negative sign of causality (the sign was established on the basis of the sum of coefficients on respective lags in the VAR model).

a, b, c—indicate that a relationship becomes insignificant when lagged DAX returns (a), volatility (b) or turnover (c) are included in a VAR model.

As in the previous cases, DAX returns significantly impact returns on the smaller CEE stock markets. It also (negatively) impacts volatilities on those markets. However, the causality running to ATX volatility can be explained by the impact of DAX volatility, which also positively causes trading activity on the VSE. On the other hand, it is interesting to highlight the significant causality running from WIG20 volatility to DAX-related variables. However, the causalities running to DAX volatility and turnover, can be explained by domestic causalities on the FSE. Nevertheless, the impact of WIG20 volatility on DAX returns remains significant even when lagged DAX volatility or turnover is added to the respective VAR model. This leads to an interesting negative bidirectional causality between DAX returns and WIG20 volatility.

The results presented in *Table 5* indicate a visible change in the information flow on the stock markets under study and between them. Announcements of US macroeconomic indicators dramatically increase the number of significant relationships. These results once again confirm the dominant role of the Frankfurt Stock Exchange in business decisions taken by investors on the CEE markets. However, some significant relationships in the opposite direction, i.e. from the stock exchange in Warsaw to the FSE, are also observed. In contrast, the Vienna Stock Exchange does not seem to be a source of additional information to investors on either of the other markets.

We repeat the above analysis in afternoon periods, but restricted to days with good (bad) news only. This shows the difference in the impact of each kind of news on causalities between the markets.[16] Good news announcements are accompanied by 16 causal relationships, both domestic and cross-country. Most of them run form DAX-related variables and, in general, they are in line with the results in *Table 5*.

However, when bad news is announced, only five significant causalities are observed. Also, heterogeneous or neutral news leads to only seven significant causal relationships. Irrespective of the kind of news, causality from DAX returns to ATX returns is highly significant while causality from DAX returns to WIG20 returns is highly significant only in the case of heterogeneous news. When bad (good) news is announced, it is significant at the 5% (10%) level. This shows how relationships between the market depend on the kind of news announced. It can be explained by asymmetries in investors' reactions to bad and good news. For example, as indicated by Gurgul and Wójtowicz (2014), bad news implies a stronger reaction of the WIG20, whereas the impact of good news is significant for a longer time.

5. Summary

This paper tries to fill a gap in the existing literature by analyzing the impact of US macroeconomic news announcements on dynamic relationships between intraday returns, volatility and trading volume on selected European markets. We investigate Granger causality on the three stock exchanges in Frankfurt, Vienna and Warsaw. The first of these is a large, developed market, while the other two are rather small markets that compete for leadership in the Central and Eastern Europe region. The analysis presented in this paper is based on five-minute data of the main indices of these stock markets (DAX, ATX and WIG20, respectively) in the period from March 22, 2013 to September 5, 2013. We analyze the relationships in periods with and without important macroeconomic news announcements. These announcements are applied as a proxy for important publicly available information.

The first important conclusion is about the role of macroeconomic news announcements with respect to the structure of causal links on the markets under study and between them. The empirical results of this paper confirm the strong impact of announcements of macroeconomic news about the US economy on the structure of causalities between returns, volume and volatility on the three European stock markets under study. When important publicly available macroeconomic news is announced, the number of statistically significant causalities increases considerably and new information is transmitted between the markets through a variety of channels. This confirms a strong spillover effect between the markets.

Our study confirms the dominant role of the Frankfurt Stock Exchange. The most significant relationships are causalities running from DAX returns to the returns of the ATX and those of the WIG20. These links are observed irrespective of the time of day and the presence/absence of important macroeconomic US news announcements. The significant causalities running from DAX returns to returns of the WIG20 and ATX suggest the possibility of using DAX data to improve the modeling and forecasting of stock prices on CEE stock markets.

A large share of the overall number of causal links between the WSE and VSE become insignificant when lagged DAX returns, volatility and turnover are included in the respective VAR models. In other words, the impact of DAX returns, volatility and turnover also explains most of the causal relationships observed

[16] Due to the relatively small samples corresponding to days with each kind of news (when compared to the whole sample of days with US macroeconomic news announcements), these results must be treated only as indicative. Hence, we present only the main conclusion from these analyses.

on the CEE stock markets and between them. However, some of the causalities on the Warsaw Stock Exchange are unaffected by the DAX. Moreover, in periods with US macroeconomic news announcements, WIG20-related variables significantly impact the characteristics of the FSE. This type of feedback is not observed for the ATX, and therefore the Vienna Stock Exchange seems to be the least important among the stock markets under study. Except for relationships induced by the DAX, the ATX does not impact the WIG20 either. Moreover, neither CEE market seems to interact with the other. These results are in line with the outcomes of previous papers indicating the strong impact of large developed Western European stock markets on smaller CEE markets and very weak connections between the stock markets in Central and Eastern Europe.

The lead-lag relationship between returns, volatility and turnover observed on the FSE and WSE in periods with important US macroeconomic news announcements supports the *Sequential Information Arrival Hypothesis*. On the other hand, the results of the analysis of domestic causalities in periods with no news announcements do not contradict the rationality.

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