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Expiration day effects of stock and index futures on the Warsaw Stock Exchange

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Abstract

This paper examines the impact of stock and index futures expirations on the spot market on the Warsaw Stock Exchange. Three of the most commonly-observed effects are analysed, namely increased trading volume of the underlying asset, abnormally high volatility of returns on the expiration day and a price reversal after the expiration. The study confirms that index futures expirations induce increased trading activity of investors, reflected in abnormally high turnover and relative turnover values of stocks from the index. In the case of single stocks, however, all three effects are observed. The reversal of stock prices takes place just after futures expiration and is reflected in the opening prices on the next trading session. Additional analysis performed in sub-periods reveals a significant impact of changes in the short selling rules introduced in May 2015 on expiration day effects.

Keywords: futures market, expiration day effects, stock market, event study

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1 Introduction

Stock or index futures, as other financial derivatives, were introduced as useful tools for hedging stock market risk. However, they have also been widely applied for speculative reasons. Very high activity of investors implementing speculative or arbitrage strategies on stock and index futures may conduce to undesirable anomalies in markings of futures' underlying assets. These artificially induced price movements give false signals to uninformed traders and distort the process of discovering prices on the stock market. This adverse impact of the futures market on the stock market is particularly strong on the expiration days of these derivatives.

Expiration day effects of futures markets have been discovered on various stock markets such as the US, Canadian, German, Swedish, Japanese, Indian, and Australian stock markets (see, for example Karolyi 1996; Schlag 1996; Stoll, Whaley 1997; Alkebäck, Hagelin 2004; Vipul 2005; Debasish 2010; Tripathy 2010; Narang, Vij 2013; Fung, Jung 2009; Illueca, Lafuente 2006; Chow et al. 2013; Mahalwala 2016). These studies have specified three of the most commonly-observed expiration day effects: an increased trading volume of the underlying stock or index on the expiration day; an abnormally high return volatility on the expiration day; and a price reversal after the expiration.

One of the sources of the expiration day effects can be seen in the activity of arbitrageurs. If, during the contract life, its internal value differs significantly from its market value, investors have an opportunity to earn on this anomaly by holding a long position on a future and a short position on its' underlying asset, or vice versa, depending on the sign of the difference. These positions are often unwound on future expiration days. If many arbitrageurs unwind their positions in the same direction, price effects may occur (Alkebäck, Hagelin 2004; Chay 2011).

Speculators, who make up a vital group of investors trading on the futures market, may also contribute to the occurrence of expiration day effects. As the final settlement price of the contract is calculated on the basis of underlying asset prices from the expiration day, speculators are interested in manipulating the price so that the contract would be settled at a price profitable for them. Usually, such a price differs from the true value of the asset. However, on an effective market, an incorrectly priced asset attracts the attention of rational investors who take advantage of the opportunity. As a result, the price very quickly moves back to its intrinsic value. The change in the asset price implied by expiration day speculations is mainly temporal, but takes place just before the end of a trading day. Hence, a significant price reversal might be observed after the expiration day. Additionally, high activity of various groups of investors on the expiration day or just before the end of a trading session may lead to high trading volume and increased return volatility.

In this paper, we investigate expiration day effects on the Warsaw Stock Exchange. The WSE seems to be a perfect candidate to study expiration day effects on. First, both futures and underlying shares are traded on the WSE. Second, it is the largest stock market in the CEE region, and thus it provides enough liquidity to apply methodology and models from large developed markets. On the other hand, in the period under study, the WSE was seen as an emerging market, so it is expected to have been less efficient than Western European developed markets and expiration day effects are expected to be better pronounced on it. Successful application of arbitrage strategies or speculation is much more difficult on deep and effective developed markets because it needs more funds to be involved. Hence, the adverse impact of futures on a spot market is expected to be particularly visible on smaller, emerging markets where there are more opportunities to speculate.

There is very little research on expiration day effects on the Polish derivatives market. To our best knowledge, the only research in this field was conducted by Morawska (2004, 2007) and Suliga (2017). However, the studies of Morawska (2004, 2007) cover the very beginning phase of the development of the derivatives market in Poland. Moreover, the analysis is performed on WIG20 index futures only, while on the WSE there are also futures listed on the mWIG40 index and futures on individual stocks. The impact of single stock futures as well as index futures on the spot market was examined by Suliga (2017), but she studied price reversal only.

This paper extends the previous studies on the impact of derivatives on the spot market on the WSE, giving a comprehensive analysis of all three expiration day effects performed on the basis of the more recent data. In this study, we examine and compare how index futures and single stock futures influence trading volume, volatility and prices of the underlying assets. The comparison of the results of the paper with the previous results from the literature, particularly concerning developed markets, will show similarities and differences in expiration day effects on the WSE and on these markets. It will also be an indicator of the degree of the development of the Polish stock market.

The important goal of the analysis is the examination of the dynamics of interrelationships between derivative and spot markets in Poland. The results can give valuable hints to regulators on whether the settlement procedure defined on the futures market works properly or if it needs to be adjusted or corrected to prevent adverse influence of the derivatives market on the spot market.

Additional analysis in sub-periods shows how expiration day effects on the WSE have changed over the recent years.

To the best of our knowledge, this research is the first conducted on the WSE in recent years which covers all of the expiration day effects. Except for the paper of Suliga (2017), it is also the only study that involves the effects of individual stock futures expirations. Thus, the contribution of the work to the research on futures' expiration day effects on the WSE is meaningful.

The structure of the paper is as follows. The next section describes previous literature on expiration day effects and is followed by a section presenting the data and empirical methodology. The results of the research are described and discussed in Section 4. Section 5 concludes the paper.

2 Literature review

2.1 Volume effects

Most of the foregoing studies on expiration day effects confirm the existence of increased trading volume on an expiration day. This anomaly was first detected by Stoll and Whaley (1986) on the New York Stock Exchange when index futures and index options expired. They found that on quarterly Friday expirations when futures on S&P500, as well as options on S&P500 and S&P100 expired simultaneously, the daily market trading volume was about 8% higher than the average daily total volume in the expiration week. On the other hand, in weeks without derivatives' expirations the difference was only about 0.2%. Moreover, the changes in trading activity were not uniform during the whole trading session on the expiration day. The trading volume in the last trading hour on expiration Fridays was about 58% higher than the average hourly trading volume during the rest of the day. On non-expiration Fridays, completely different relationships were observed because the last-hour volume was smaller than the trading volume computed during other hours of the trading session. As a result of these differences, the average last-hour trading volume on expiration Fridays was about twice as high as on non-expiration Fridays. Very strong volume effects in the last hour of trading on futures and options on S&P500 index expirations were also confirmed in the more detailed analysis of Stoll and Whaley (1987).

After this first research, volume effects were investigated on various markets and confirmed among others on the spot market in Germany (Schlag 1996), Australia (Stoll, Whaley 1997), Sweden (Alkebäck, Hagelin 2004), India (Vipul 2005; Debasish 2010; Tripathy 2010; Narang, Vij 2013; Mahalwala 2016), Poland (Morawska 2007), China (Fung, Jung 2009), Spain (Illueca, Lafuente 2006), and Taiwan (Chow et al. 2013).

Despite analysing the same effect, some of these papers differ considerably. They present various measures and definitions of extended trading volume or they examine expiration day effects only in the case of futures or simultaneous impact of futures and options expirations. For example, Schlag (1996) analysed the impact of expirations of options and futures on the DAX index in the period from September 1991 to December 1994. He found that on quarterly expiration Fridays when futures and options expired simultaneously, the total daily trading volume of stocks from DAX was about 3.5 times higher than on other Fridays. On the other hand, on monthly expiration Fridays of options only, the number of shares traded was much lower. Hence, Schlag (1996) concluded that the observed volume effect was mainly due to futures expirations.

Stoll and Whaley (1997) examined volume effect on the Australian market between January 1993 and June 1996. As a measure, they used the relative trading volume for stocks from the AOI index defined as the ratio of the dollar trading volume from the last 30 minutes of the expiration day to the total dollar trading volume on that day. As a result, Stoll and Whaley (1997) showed that the relative trading volume from expiration days was usually higher than on control days, defined as non-expiration Fridays one and two weeks prior to the expiration days.

Alkebäck and Hagelin (2004) investigated the impact of simultaneous expiration of futures and options on the Swedish OMX index between January 1988 and December 1998, dividing the period into two sub-periods: before and after the removal of the transaction tax in December 1991. The detrended trading volumes of all stocks from the OMX index for expiration days were compared with the same measure for control days as defined in Stoll and Whaley (1997). A comparison was also made between whole expiration week and the corresponding control weeks. Alkebäck and Hagelin (2004) observed increased trading volume not only on the expiration days (on average, trading volume was about 9.4% higher on expirations than on control days), but also on earlier days from the expiration week. The authors suggested that this early increase in trading volume was caused by arbitrageurs unwinding their positions on spot and derivatives markets before expiration to mitigate the risk coming from the final settlement price of the contract. A similar observation was made, for example, by Debasish (2010) on the Indian market in the case of NSE Nifty index futures expirations between June 2000 and May 2009. On the other hand, other authors (Stoll, Whaley 1986; Illueca, Lafuente 2006; Morawska 2007) found that if the final settlement price of the derivative depends on the underlying asset's prices from a very short time period (usually from the last hour of trading on the expiration day) or only on the closing price, then increased trading volume indicating intensified trade on the underlying asset of expiring derivatives took place, especially in the final trading phase of the expiration day.

2.2 Volatility effects

Similar to trading volume, increased volatility implied by expiration of derivatives was detected, for example, in the USA (Stoll, Whaley 1986; Day, Lewis 1988; Diz, Finucane 1998), Australia (Stoll, Whaley 1997; Lien, Yang 2005), Canada (Chamberlain, Cheung, Kwan 1989), Sweden (Alkebäck, Hagelin 2004), Spain (Illueca, Lafuente 2006), Poland (Morawska 2007), India (Narang, Vij 2013; Agarwalla, Pandey 2013), and Taiwan (Chow et al. 2013).

To assess the impact of expiration on S&P500, Stoll and Whaley (1986) used two measures of index volatility, namely the standard deviation of daily returns of an index and its absolute abnormal returns. They computed and compared them for three types of days: expiration of S&P500 futures, expiration of CBOE options, and Fridays when nothing expired. The same volatility measures were calculated for the data from the last hour of trading. Stoll and Whaley (1986) found that the increased volatility on expiration is not observed for daily data, but it is visible when intraday returns are analysed. More precisely, quarterly expirations, when futures on S&P500 expired, imply significantly greater volatility in the last 30 minutes of trading. On the other hand, the effect is much smaller when options expire. These effects were observed only on stocks from S&P500, while there were no price effects on non--S&P500 stocks. In line with these results, Alkebäck and Hagelin (2004) suggest that close-to-close returns were unable to properly reflect price distortions implied by futures expiration. For this reason, as a measure of volatility they proposed to apply a daily price range, defined as the natural logarithm of the highest price divided by the lowest price on the day. However, the results of the analysis of volatility effects with this measure and with standard deviation of daily returns were similar. Significantly higher volatility of the OMX index on expirations was detected only in the period 1988–1991 before the removal of the transaction tax.

Vipul (2005) also pointed out that closing prices do not contain enough information about changes in volatility. Thus, he estimated the daily volatility using the difference between the maximum and minimum price divided by its average to make the measure comparable across all shares and time periods. His study, investigating expiration day effects of index and single stock derivatives in India between November 2001 and May 2004, revealed that volatility of underlying shares was not significantly affected by the expiration of futures and options.

Xu (2014), who analysed expiration effects of index futures and options in Sweden, also applied a high-low estimator to measure volatility. However, she did not detect statistically significant differences between volatility on expiration Fridays and non-expiration Fridays.

2.3 Price reversal

If the underlying asset price on the expiration day increases or decreases as a result of speculators' activity or due to the fact that many arbitrageurs unwind their positions in the same direction, it deviates from its fundamental value. On the effective market, this incorrectly priced asset should be very quickly spotted by other investors and the price should come back to the "normal level" by movement in the opposite direction. As a result of these activities, a price reversal on the day after the expiration may occur. Reversal of the underlying asset price was defined by Stoll and Whaley (1986) as a change of the sign of the return on the following day in comparison to its sign on the expiration day. To check the existence of price reversal after index futures and options expirations, Stoll and Whaley (1986) applied various measures. One of them was computed on daily returns, while the others compared returns from the last 30 minutes of the expiration day with returns from the first 30 minutes of the next trading session. They also analysed correlation between daily returns from the expiration day and from the next day. Stoll and Whaley (1986) found the price reversal after expirations of futures on S&P500. The average reversal when futures expired was 0.38% for the S&P 500 index, 0.53% for the S&P100 index, and 0.46% for non-S&P100 stocks. In those cases, the serial correlation of returns was also negative. On the other hand, no reversal was found for non-S&P500 stocks. Except for S&P500, there was also a small reversal when nothing expired, but it was not connected with negative serial correlation. Analogous results were obtained on the detailed research of S&P500 futures expiration conducted one year later (Stoll, Whaley 1987). In their other research (Stoll, Whaley 1991), which investigated whether the change in the settlement of S&P500 and NYSE index futures and options contracts had an impact on expiration effect, the authors proposed one more measure of price reversal of the index, namely portfolio reversal based on portfolio returns.

The anomaly of price reversal was also confirmed by Chamberlain, Cheung and Kwan (1989), Schlag (1996) and Suliga (2017), who applied some of the measures from Stoll and Whaley (1986, 1987, 1991). However, other studies on this effect did not find any symptom of the reversal (e.g. Karolyi 1996; Stoll, Whaley 1997; Alkebäck, Hagelin 2004; Morawska 2007; Fung, Jung 2009; Narang, Vij 2013). Vipul (2005) suggests that the definition of price reversal given by Stoll and Whaley (1986, 1987, 1991), "ignores the total quantum of change in price, both in the same direction and in the opposite direction." For this reason, he decided to study price shock around expiration rather than the price reversal. He found abnormally high rates of increase of returns on the day after the expiration. In most of the cases it is not the price reversal, but Vipul (2005) suggested that, "it certainly indicates a sudden upward acceleration in the prices after the expiration day, irrespective of the increase or decrease in the price on the expiration day", which can be seen as a price effect of expiration. Price shock was also examined by Xu (2014) on the Swedish market, but she did not find any significant changes in price reversals and price shocks on expiration and non-expiration days.

The limitation of Stoll and Whaley's (1986) definition of price reversal was also noticed by Suliga (2017) who analysed a change of the sign of abnormal returns computed as the difference between observed and expected returns.

2.4 Expiration day effects on the WSE

Expiration day effects of futures on the Warsaw Stock Exchange have been studied by Morawska (2004, 2007) and Suliga (2017). Morawska (2004, 2007) examined only the influence of the expiration of WIG20 index futures on returns of the index itself and on trading volume of the stocks from it. The results confirmed the effect of increased trading volume of the stocks and increased volatility of intraday returns of the index, but did not reveal price reversal of index returns after the expiration. It should be noted that Morawska carried out her research for the initial years of futures trading on the WSE and she studied only futures on the WIG20 index, as, in those years, the volume of futures on WIG20 formed about 97% of the whole volume on the derivatives market. Suliga (2017) largely extended the period under study by considering the expiration days from 2001 to 2016. Beside futures on

WIG20, she also analysed the impact of futures on mWIG40 and futures on individual stocks. To study the effect of price reversal after expiration, Suliga (2017) employed three different measures. All of them supported the thesis that price reversal in stocks' returns occurs after expiration of stock futures, but none of them confirmed the reversal in WIG20 and mWIG40 returns.

2.5 Price settlement procedures for futures contracts and expiration day effects

Results from research conducted on different foreign markets indicate that the way futures contracts are settled is a very important factor leading to expiration day effects or preventing them.

Stoll and Whaley (1986), who studied expiration day effects of futures on the S&P500 index and futures on the MMI index, verified that in the case of contracts that were settled at a closing index level on the expiration day, the activity of investors was intensified in the last minutes of trade, triggering expiration day effects. Similarly, an increase in trading volume and return volatility at the maturity of Ibex35 futures on the Spanish equity market was detected by Illueca and Lafuente (2006). The strongest volume and volatility effects were observed within the final interval of trading on expiration day (16:00–17:30) while the settlement price of these contracts was calculated as the arithmetic average of index values between 16:15 and 16:45.

Morawska (2007), who studied the expiration day effects of these futures in the period 2002–2006, detected significantly higher volatility of stocks from the index during the last hour of trading on expiration Fridays in comparison to non-expiration Fridays. Another confirmation of the fact that expiration day effects depend on the settlement procedure of futures contracts is the research on the effects of Hang Seng Index futures expirations conducted by Fung and Jung (2009) on the Chinese stock exchange. The final settlement price of these contracts was equal to the arithmetic average of the index values taken every five minutes on the whole expiration day. The authors demonstrated that close to the five-minute time marks, trading activity intensified both in frequency and volume.

Alkebäck and Hagelin (2004), who studied expiration day effects of futures and options on the Swedish OMX index, verified that if the settlement price of a derivative was based on intraday quotes of the underlying asset from the whole expiration day, the possibility of influencing the settlement price was limited and the price was easier to estimate. In fact, they showed that trading activity intensified during expiration week and on expiration day, but they did not find any sharp price movements on the expiration. According to them, a long settlement period helps to curb such unusual changes in stock prices and the activity of speculators and arbitrageurs did not cause any price distortion.

To check if the occurrence of the effects depends on the settlement price of the contract, Hsieh and Ma (2009) compared expiration day effects of two index futures with different settlement mechanisms which have the same underlying spot market. They found that to minimize the effects, "the average price is better than the opening price, which in turn is better than the closing price settlement."

From the abovementioned results, it follows that expiration day effects can occur particularly in the period of time from which the prices of underlying assets are used to calculate the final settlement price of the contract. Hence, the longer the settlement period is, the weaker the effects are.

On the WSE, the settlement price of futures on the WIG20 index, as well as futures on the mWIG40 index, is equal to the trimmed average of values of continuous trading of an index from the last hour of trading and the value at close. Before computing, the average 5 highest and 5 lowest values are removed. On the other hand, individual stock futures traded on the WSE are settled at a closing price. Thus, we expect the effects to be stronger in the case of single stock futures. However, it should be mentioned here that most of the stocks analysed in the paper are from the WIG20 index. As stock futures and index futures expire on the same days, the effects that can be seen in stock quotes may arise from both index futures and stock futures expirations. Although we expect expiration day effects on the WSE to exist, the use of daily data in this study may make it difficult to detect them if they occur in a short period of time. Thus, to detect price reversal, next to day-to-day returns, we also use overnight returns, as Alkebäck and Hagelin (2004) suggested that this effect can take place long before the markets close on the day following expiration.

3 Data, methodology and research hypotheses

In this paper, we examine the effect of increased volume, volatility and price reversals after expiration of individual stocks futures and on index futures on WIG20 and mWIG40. Hence, our dataset contains daily open, close, maximum, and minimum price and turnover value of WIG20, mWIG40 and underlying stocks from the WSE. For single stocks, we also take into account daily trading volume. Data covers the period from January 2001 to the end of December 2016. Due to quarterly expiration of index futures on the WSE, within the period under study there are 64 expiration days of futures on WIG20 and 60 expirations of futures on mWIG40 (the first futures on the stock market index of medium-sized companies expired in March 2002; in May 2007, the name of the index was changed from MIDWIG to mWIG40). The first futures on individual stocks were introduced in 2001, but before 2003 some of the stock futures (e.g. futures on PKN) used to expire every month. Since 2003, all futures on stocks have had the same expiration days as index futures that are third Fridays of the quarterly months (i.e. March, June, September, and December). Hence, to have in the sample futures with the same expiration days, we decided to study only stock futures expiring after January 2003. Table 1 presents a detailed list of futures under study together with information about the first expiration date and the number of expirations analysed. Not all expirations of futures were taken into account. We consider only stock futures with at least one opened position on the expiration day. Futures with no opened positions on the expiration were excluded from the sample.

To study the expiration day effects, we employed two different methodologies. The first one is based on a comparison of measures of the effects computed for expiration days and for control days. This stream of research was proposed by Stoll and Whaley (1986, 1987, 1991). In the following years, it has been used, inter alia, by Bollen and Whaley (1999), Alkebäck and Hagelin (2002), Morawska (2007), Hsieh (2009), Chay, Kim and Ryu (2013) and Xu (2014). Following Suliga (2017), in addition to classical measures of expiration day effects, we also used event study analysis as a second method of research.

3.1 Measures of expiration day effects

In foregoing studies on expiration day effects, authors have constructed various measures of expiration day effects. The most common method of analysis was the comparison of these measures computed for expiration days and for appropriately defined control days. Such a comparison was first proposed by Stoll and Whaley (1986, 1987, 1991) and then used by others (see, for example, Bollen, Whaley 1999; Alkebäck, Hagelin 2002; Morawska 2007; Hsieh 2009; Chay, Kim, Ryu 2013; Xu 2014). In the first part of our study, we will follow this methodology.

Trading activity

To measure volume effects on expiration days, we apply two measures: V_t – natural logarithms of daily turnover on the day t and relative turnover RV_t defined as a daily growth rate of turnover value for the stock or index:

$$RV_t = \ln\left(\frac{V_t}{V_{t-1}}\right) \tag{1}$$

A comparison of V_t on expiration days and on control days reveals how much higher (or lower) the trading activity on expiration days is than is usual on other Fridays. On the other hand, RV_t describes the dynamics of changes in trading activity from one day to another. The comparison of RV_t on expiration and non-expiration days will show whether the changes in the trading activity from Thursday to Friday are implied by futures expirations.

Bollen and Whaley (1999), as well as Xu (2014), considered measures analogous to RV_t, but defined on the basis of daily trading volume (a number of shares traded) instead of the turnover. We decided to apply the total value of shares traded as the main measure of trading activity because, in the case of stock market indexes (such as WIG20 and mWIG40), turnover is a more appropriate measure of trading activity. The trading volume of an index, defined as the sum of the trading volume of all its stocks, is an incorrect measure of the trading activity, because it may be dominated by the trading volume of a single stock with very cheap but numerous shares. However, in order to ensure comparability of this study with the previous results, in the analysis of expiration day effects implied by single stock futures we will apply measures based on the trading volume as well.

Volatility

In order to study the impact of expiration on stock price volatility, we apply a variety of measures. First, we consider absolute values of daily stock or index returns $|R_t|$ computed on the basis of closing prices, because absolute (or squared) returns are one of the most commonly used measures of daily stock price volatility. To take into account only volatility during the continuous trading phase, we consider absolute values of returns R_t^{oc} from opening to closing of a trading session:

$$R_t^{oc} = \ln\left(P_{t,\,close}\right) - \ln\left(P_{t,\,open}\right) \tag{2}$$

Intraday volatility of prices is also estimated on the basis of the difference between maximum and minimum price. More precisely, we use the estimator proposed by Vipul (2005):

$$VOL_t = \frac{P_{t,max} - P_{t,min}}{\frac{1}{2}\left(P_{t,\,max} + P_{t,\,min}\right)} \tag{3}$$

where $P_{t,\,max}$ and $P_{t,\,min}$ are the maximum and minimum prices of the stock (or index) on day t, respectively.

Parkinson (1980) showed that when the prices are log-normally distributed, then estimates based on differences between $P_{t,\,max}$ and $P_{t,\,min}$ are about five times more efficient than those based on closing prices. Moreover, these estimates are robust when the price distribution is not log-normal.

Price reversal

To study the price reversal effects, we analyse the behaviour of the overnight returns just after the expiration day. Thus, the price reversal measure after the expiration is defined as in Xu (2014) as:

$$REV_t^{ON} = \begin{cases} R_t^{co} & \text{if} \quad R_{t-1}^{oc} < 0 \\ -R_t^{co} & \text{if} \quad R_{t-1}^{oc} \geq 0 \end{cases} \tag{4}$$

where $R_{t-1}^{oc} = \ln\left(P_{t-1,\,close}\right) - \ln\left(P_{t-1,\,open}\right)$ is the log-return from the expiration (or control) Friday and $R_t^{co} = \ln\left(P_{t,\,open}\right) - \ln\left(P_{t-1,\,close}\right)$ is the overnight log-return just after the expiration (or control) day computed on the basis of the opening price on the next day (usually it is Monday) $P_{t,open}$ and $P_{t-1,\,close}$ the closing price $\left(P_{t-1,\,close}\right)$ from the expiration (control) day.

Its interpretation is as follows: if there is a price reversal and the price changes its direction immediately after the futures expiration, then negative returns R_{t-1}^{co} on an expiration day are followed by positive overnight returns R_t^{co}, and vice versa, negative overnight returns R_t^{co} follow positive returns R_{t-1}^{co} on the expiration day. Hence, significantly positive REV_t^{ON} indicate reversal of price direction during the night after futures expiration, while significantly negative REV_t^{ON} are indicators of price continuation.

A measure of price reversal similar to the above was first proposed by Stoll and Whaley (1986, 1987, 1991) and then employed by others (e.g. Chamberlain, Cheung, Kwan 1989; Alkebäck, Hagelin 2004; Xu 2014). However, in the first two articles, Stoll and Whaley defined it in terms of daily close--to-close returns on expiration day and on the next day. Stoll and Whaley (1991) used returns from the last-half hour of trading on expiration Friday and the first half-hour return on the next day. Alkebäck and Hagelin (2004) suggested that day-to-day returns may be unable to reflect price reversal because it takes place long before the market close the day after the expiration. If the reversal is immediate, it can be reflected even in the opening price on the day after expiration. Hence, we use the post-expiration overnight rather than daily returns in the analysis.

To measure the speed of potential price reversal, we also consider a price reversal measure based on close-to-close returns from the whole day after futures expiration:

$$REV_t = \begin{cases} R_t & \text{if} \quad R_{t-1}^{oc} < 0 \\ -R_t & \text{if} \quad R_{t-1}^{oc} \geq 0 \end{cases} \tag{5}$$

where $R_t = \ln\left(P_{t,\,close}\right) - \ln\left(P_{t-1,\,close}\right)$ is simply a daily return. This measure was applied by Suliga (2017).

Control days, which form the background for the comparison of the measures computed on expiration days, are defined in two different ways. In the first case (control days I), the measures computed for the first, second and fourth Friday of an expiration month are averaged to represent one control day. This approach ensures an equal number of the compared values of a measure from expiration and control days. In the second case (control days II), the control values are computed on the third Fridays of months without expiration. Thus, for each expiration day, the results for the third Friday of the preceding month and the third Friday of the following month are averaged to give one control value. The procedure of averaging observations from a few control days to one benchmark was also employed by Vipul (2005). Comparison of the results for expiration days with control days II also shows the impact on stocks from the WSE of futures expirations on other markets, particularly on Eurex, where futures contracts expire every month.

The values of the expiration day effects measures computed for expiration days and control days are compared with the use of the nonparametric Mann-Whitney U test (see Mann, Whitney 1947), which verifies whether there is a significant difference in their distributions. An unquestionable advantage of this test is the fact that it does not assume normality of data and therefore is more robust that the parametric t-test.

3.2 Event study analysis

In the second part of the research, we apply event study methodology to study expiration day effects on the WSE. This method was first applied to this issue by Suliga (2017) in the analysis of price reversal effect. We apply this methodology to study the impact of expiration day trading volume, volatility, and prices of the underlying assets.

First of all, we must define what we mean by the event. In this paper, the event is the expiration of futures. For such an event, we study how prices, volatility and trading activity measure for the underlying stock change just before and just after it. To do this, we define the pre-event and the event windows as follows. Let us denote the expiration day by $t = 0$. The event window starts five days before the expiration and ends two days after it ($t = -5, \ldots, 2$). Such a span of the event window is dictated by the suggestions from foregoing studies that expirations effects can be observed over a week before an expiration as a result of early unwinding of arbitrage positions (e.g. Stoll, Whaley 1986; Alkebäck, Hagelin 2004). The price reversal is the only effect that may occur after the expiration. As this phenomenon should be observed immediately after the expiration, we decided to include in the event window only two days after the expiration. We define the pre-event window as widely as possible in order not to overlap with the previous event window. Because futures on the WSE expire quarterly, the optimal choice is to define the pre-event window to cover 45 trading days before the event window ($t = -50, \ldots, -6$). The length of the pre-event window is chosen to prevent the occurrence of confounding events. The pre-event window almost reaches the event window of the previous expiration, but these windows do not overlap and the previous expiration day is not included in the pre-event window of the next expiration.

The fact that the same estimation window (and slightly wider event window starting five days before the expiration and ending five days after it) was used by Suliga (2017) enables us to compare our results with those she obtained.

The analysis of the impact of the futures market on the spot market is performed by testing whether turnover or volatility on the expiration day (or prices on the next day) deviate from their "normal" values. The appropriate test statistic is constructed on the basis of abnormal variables $AX_{i,t}$

defined for the i-th event as the difference between the value of the respective variable $X_{i,t}$ and its expected value $E(X_{it} \mid \Omega_{-6})$ conditional to data from the pre-event window, i.e. data set Ω_{-6} at t = -6:

$$AX_{i,t} = X_{i,t} - E(X_{it} \mid \Omega_{-6}) \tag{6}$$

In this paper $E(X_{it} \mid \Omega_{-6})$ is approximated by the average from the pre-event window. Because we study three different effects, three different kinds of variables $X_{i,t}$ are considered according to volatility, volume and price effects studied, namely natural logarithms of daily turnover value $\ln\left(v_{i,t}\right)$, daily volatility measure $VOL_{i,t}$ defined in Subsection 3.1, and the overnight log-returns $R_{i,t}^{co}$

On the basis of abnormal variables given by formula (6), we verify whether the futures market significantly impacts the spot market at $t = t_0$ by testing the following hypotheses:

$$\begin{aligned} &H_0 : E\left(AX_{it_0}\right) = 0 \\ &H_1 : E\left(AX_{it_0}\right) \neq 0 \end{aligned} \tag{7}$$

To verify these hypotheses, we apply the Kolari-Pynnönen test statistic, which verifies the significance of the mean of the abnormal variables in the event window. To compute the test statistics, we group events into clusters and then for each event i (i = 1,…, N) in the cluster, the values of the abnormal variable $AX_{i,t}$ in the event and pre-event windows are divided by their standard deviation from the pre-event window. The resulting standardized abnormal variables have the form:

$$SAX_{i,t} = AX_{i,t} / S\left(AX_i\right) \tag{8}$$

where $S(AX_i)$ is the standard deviation of forecast errors, which in the case of the constant mean model takes the form:

$$S\left(AX_i\right) = \sqrt{\frac{1}{44} \sum_{t=-50}^{-6} \left(AX_{i,t} - \overline{AX_i}\right)^2} \tag{9}$$

$$\overline{AX_i} = \sum_{t=-50}^{-6} AX_{i,t} \tag{10}$$

Then, to take into account an event-induced increase in volatility, standardized abnormal variables $SAX_{i,t}$ on each day t in the event window are divided by their cross-sectional standard deviation to obtain adjusted standardized abnormal returns:

$$SAX_{i,t}^{'} = \begin{cases} SAX_{i,t} & t = -50,\ldots,-6 \\ SAX_{i,t} / S\left(SAX_t\right) & t = -5,\ldots,2 \end{cases} \tag{11}$$

where $S(SAX_t)$ is the cross-sectional standard deviation of $SAX_{i,t}$ on t-th day:

$$S\left(SAX_t\right)=\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(SAX_{i,t}-\overline{SAX}_t\right)^2} \tag{12}$$

and N is the number of events in the cluster. Under the null hypothesis of no event effect, for given t_0 in the event window, SAX'_{i,t_0} are zero mean and unit variance random variables. For each day $t_0 \in \{-5,\ldots,2\}$ separately, we test the significance of abnormal variables with the use of standardized ranks defined as:

$$U_{i,t}=\frac{rank\left(SAX'_{i,t}\right)}{47}-\frac{1}{2} \tag{13}$$

where $t \in \Omega = \{-50,\ldots,-6,t_0\}$ and $i=1,\ldots,N$, and $rank\left(SAX'_{i,t}\right)$ denotes the rank of $SAX'_{i,t}$ within the vector of adjusted standardized abnormal variables from the pre-event window and $SAR'_{i,t0}$.

The null hypothesis of no event effect means that $E\left(U_{i,t_0}\right)=0$. To test this hypothesis, Kolari and Pynnönen (2011) propose a generalized rank test with the test statistics τ_{grank} defined as:

$$\tau_{grank}=Z\sqrt{\frac{T-2}{T-1-Z^2}} \tag{14}$$

where:

$$Z=\frac{\overline{U}_{t_0}}{S_{\overline{U}}},\quad \overline{U}_{t_0}=\frac{1}{N}\sum_{i=1}^{N}U_{i,t_0},\quad S_{\overline{U}}=\sqrt{\frac{1}{46}\sum_{t\in\Omega}\overline{U}_t^2} \tag{15}$$

If the null hypothesis is true, the distribution of τ_{grank} statistics converges to *t*-Student distribution with 44 degrees of freedom when the sample size N increases to infinity.

To verify the existence of price reversal after the expiration, the overnight returns are divided into two separate clusters according to the sign of the abnormal returns from open to close on the expiration day. The first cluster consists of overnight returns after the expiration days with positive daily abnormal returns (i.e. when prices increase more than expected), while the second one contains the overnight returns after the expiration days with negative daily abnormal returns (i.e. when prices decrease more than expected). In that way, we are able to analyse separately the price reversals after an unexpected increase or decrease of prices.

It should be stressed here that the method described above defines the price reversal differently, and, in our opinion, more appropriately than the measure proposed by Stoll and Whaley (1986) and employed in the first part of Section 4. In Stoll and Whaley (1986), price reversal was equivalent to the change of the return's sign, and, as was noted by Vipul (2005), "this leads to a loss of information in terms of the magnitude of total change." Here, price reversal was defined as a change in the direction in which the return significantly deviates from its expected value. The degree of discrepancy between the expected value of the return and its realised value seems to be an even more appropriate measure of the unusual price movement than the magnitude of the price change from expiration day to the next day.

The general assumption of the Kolari and Pynnönen (2011) test is that abnormal returns are independent and identically distributed. In this study, however, we apply the test to data that do not fulfil these conditions. In the constant mean model, abnormal returns have the same properties as returns, hence frequently they are autocorrelated and heteroscedastic. Similarly, measures of abnormal trading activity (volume and volatility) show strong and significant autocorrelation. Additionally, in the case of tests for the expiration day effect on single stocks, events are clustered, and thus cross-sectional correlation of abnormal variables may be observed. In their paper, Kolari and Pynnönen (2011) applied simulations to analyse the power and size of the τ_{grank} test. As a result, they showed that for daily returns the test is robust to possible autocorrelation and heteroscedasticity. However, we don't only consider returns. Hence, we perform an analogous simulation procedure to study how various properties of data applied in this paper impact the results of the Kolari and Pynnönen (2011) test. We described the simulation procedure on the example of the WIG20 trading volume.

As it was mentioned at the beginning of this section, and as it can be noticed from Table 3, for each index we studied about 60 events of futures contract expirations. From the whole sample of daily trading volume of WIG20 in the period from January 2001 to December 2016, we randomly select 1000 samples of $N = 60$ trading volume series. Each of these series has a length of 53 days (which corresponds to the length of the pre-event and event windows from Section 3.2) and the 51st element ($t = 0$) is an event day. Then, in each sample generated in that way, we compute the value for $t = 0$. On the basis of the whole sample of 1000 values of statistics, we computed rejection rates for various significance levels. Data in the sample is randomly chosen, so the null hypothesis in the event study analysis that there is no event effect is true. Hence, the rejection rates describe Type I errors. To study the power of the Kolari and Pynnönen test in the above simulation, we add a small value P^* to trading volume on the event days. P^* is defined as a fraction of trading volume standard deviation from the whole sample.

To study the properties of the Kolari and Pynnönen test in the case of the analysis of single stock futures expiration, the simulation procedure is as follows. First, from the sample of all trading days between March 2003 and December 2016 we randomly chose 30 days. These are event days. Next, for each event day we randomly chose ¾ of stocks mentioned in Table 1 that were traded on that day. For each of these stocks we take into account data from 50 days before the event to 2 days after it. As a result, we obtain a sample of about 500–600 series corresponding to 30 event days. On the basis of these data we compute the value of τ_{grank} statistics for the event day. The whole procedure is repeated 1000 times.

The simulation procedure described above generates data in which the null hypothesis of no event effect is true. Hence, its rejection rate in a simulated sample describes a Type I error. The results presented in Table 2 indicate that for the majority of data analysed in this paper, computed empirical values of Type I errors are very close to nominal significance levels. This ensures the correctness of the results of the empirical analysis presented in the next sections. Only in the case of log-turnover and volatility measure are the rejection rates outside their 95% confidence intervals. It is particularly visible in the case of the reaction of single stocks, and it means that for this data the Kolari-Pynnönen test tends to over-reject the true null hypothesis. The possible cause of the increased values of Type I errors for that data is a conjunction of high and significant correlation observed in log-volume and volatility time series with cross-sectional correlations induced by events clustering when the reaction of various stocks to common events is analysed. To take into account this negative impact of data properties on the size of the Kolari-Pynnönen test, on the basis of simulations we computed respective empirical critical values of the test. In the case of log-turnover of single stocks, the empirical critical values for the 1%, 5% and 10% significance levels are equal to 2.91, 2.19 and 1.86, respectively. For volatility measures, they are 2.89, 2.27 and 1.91. In the empirical analysis, these values should be applied instead of theoretical critical values from *t*-Student distribution with 44 degrees of freedom which are equal to 2.69, 2.02 and 1.68. However, as we see, the differences between empirical and theoretical critical values are small, and, as it will be stressed in Section 4, these differences do not impact the results of the analysis.

3.3 Research hypotheses

On the basis of the results from foreign markets, we formulate some hypotheses about expiration day effects on the Polish equity market.

Trading activity

As the volume effect of futures expirations was detected on each of the researched markets, we expect that this effect also occurs on the Polish market. Therefore we conjecture that on expiration days turnover values of underlying stocks and indexes strongly increase above expectations, and that their values are significantly larger on expiration day than on other Fridays without futures' expirations.

Volatility

Volatility effect varies depending on the market, the period under study, the employed measure of the effect or the settlement procedure of the contract. The comparison of different settlement procedures reveals that the longer the settlement period, the weaker the effects. Thus, we suppose that return volatility of individual stocks increases as an effect of stock futures expirations. On the other hand, due to different settlement procedures, we do not expect to detect such effects in the returns of indexes.

Price reversal

As it appears from the literature, price reversal after futures expiration occurs when stock prices return to their normal level. As it is much easier to change the closing price of individual stock than to influence the average price of the index, we expect that price reversal may occur in individual stock prices, but not in indexes. Additionally, since Chay, Kim and Ryu (2013), as well as Alkebäck and Hagelin (2004), suggest that incorrectly priced stocks should revert to a normal price level immediately after the expiration, we suppose that price reversal will be reflected in overnight returns rather than in close--to-close returns.

Evolution of expiration day effects

To check how the occurrence and the strength of the expiration day effect on the WSE were changing over time, we conduct the study in four sub-periods, as follows: 2 January 2003 – 31 December 2009;

2 January 2010 – 14 April 2013; 15 April 2013 – 31 May 2015; and 1 June 2015 – 31 December 2016. Each of these sub-periods contains about 150 expirations of single stocks futures. The first sub-period covers the beginning phase of the development of the futures market on the WSE, when the number of contracts traded was limited. Thus, it is much longer than the other periods. It also includes the global financial crisis of 2007–2009. The second sub-period contains data after the crisis up to the change of the trading system on the WSE. On 15 April 2013, the WARSET trading system was replaced by the UTP, which could potentially intensify expiration day effects as a faster and more advanced system facilitates carrying out speculative and arbitrage strategies. The third breakpoint is 1 June 2015, the day when changes in the rules regarding the short selling of stocks were introduced. These changes resulted from the adaptation of the foregoing regulations of the WSE to EU requirements, in particular to Regulation 236/2012. The restrictions on short selling related to the liquidity of shares were lifted, so since then the transaction system of the WSE has accepted every short sell order. What is more, the obligation to mark short sell orders was waived. As the changes significantly facilitated short selling, they might reduce investors' interest in futures and thus reduce expiration day effects because short positions in futures can be substituted by an appropriate short selling of stocks. Moreover, these changes make arbitrage strategies on stocks and futures regarding short position in stocks easier to conduct. This may also diminish price effects because of unwinding arbitrage positions in two opposite directions. Thus, while analysing expiration day effects in the sub-periods, we do not expect drastic changes in the impact of the futures market on the spot market; however, we suppose that there can be an intensification of the effects in the third sub-period and their attenuation in the last one.

4 Empirical results

4.1 Results for classical measures of expiration day effects

To compare expiration day effects on the WSE with previous results from literature, we first apply the classical measures described in Section 3.1. Table 3 presents means and medians of log-turnover V_t and relative turnover RV_t for underlying assets of index and single stock futures. We compute these measures on expiration days as well as on control days defined in Section 3.1. The results from these two groups of days are compared on the basis of Mann-Whitney U tests, whose p-values are also presented in Table 3. We decided to apply a nonparametric test rather than a parametric one because of the well-known non-normality of stock and index returns.

The leftmost columns of Panel A confirm the existence of increased trading activity on the largest stocks from the WSE. The mean and median of WIG20 turnover on expiration days are greater than on both kinds of control days, and the Mann-Whitney tests confirm the significance of these differences. It means that trading volume on expiration days is significantly higher than on other Fridays taken into consideration, particularly on the days when futures contracts on other markets expire. The results from Panel B also indicate that not only is the turnover value of stocks from WIG20 higher on expiration days, but also its change from Thursday to Friday is the strongest on expiration days. Both these results (from log-turnover and the relative turnover) confirm the existence of the effect of increased turnover value of the WIG20 index on expiration days.

Such conclusions cannot be drawn from the results of the analysis of mWIG40 turnover. Mean and median log-turnover values on expiration days are higher than on both types of control days, but the differences are statistically insignificant. Also, the relative turnover values of mWIG40 on expirations do not differ significantly from the values obtained for control days I (the first, second and fourth Friday of an expiration month).

In the case of stock futures, significantly higher trading turnover on underlying assets on expiration days similar to the WIG20 futures is observed. Additionally, day-to-day changes of trading activity are significantly different on expiration and control days.

Comparison of the means of log-turnover from Panel A shows how much the expiration of futures increases trading activity. In the case of the largest and the most liquid stocks from the WIG20 index, turnover on expiration days is on average (in terms of geometric mean) about 50% higher than on the other Fridays of expiration months and it is about twice as high as on the other third Fridays of the month. Expiration of single stock futures raises turnover of underlying assets by about 118% and 128%, respectively. On the other hand, the changes observed in the trading activity on medium-size stocks from mWIG40 are much smaller and more insignificant. They are equal to 8% and 19%, respectively.

From Panel B of Table 3, we can notice that, on average, the turnover value of WIG20 stocks increases on expiration day by about 40% when compared to the day before. This change in investors' activity implied by futures expiration is even more pronounced in the case of single stocks, where the average growth of turnover value from Thursday to expiration Friday is equal to about 80%. On Fridays without futures expirations, turnover value of underlying stocks is, on average, lower than on preceding Thursdays.

The above results confirm that the impact of the expiration of WIG20 index futures and single stock futures on trading activity on the WSE is strong and significant, particularly when compared with results from other markets. On many of them, futures expiration increases trading activity, similar to that for the mWIG40 index. For example, Alkebäck and Hagelin (2004) showed that between January 1988 and December 1998, the total trading volume of all stocks from the OMX Index on expiration days was, on average, 9.4% higher than on control days. The average growth of the daily volume of stocks was equal to 17% on the US market in the period from June 1982 to December 1985, when S&P500 futures and S&P100 options expired simultaneously (Stoll, Whaley 1986). On the Spanish equity market, on expiration days of Ibex35 futures between January 2000 and December 2002, the total volume of the stocks was, on average, 24% higher than on control days (Illueca, Lafuente 2006). Similar results were obtained on Asian markets: the average volume growth of stocks from the Hang Seng Index was equal to 19% when index futures expired (Fung, Jung 2009), while on the Indian market such growth reached 6% on the NSE Nifty Index futures expirations (Debasish 2010).

Results of the analysis of how expiration impacts return volatility presented in Table 4 are not as clear as the results from Table 3. All the differences between volatility measures based on opening and closing prices on expiration and control days are insignificant at the 5% level. However, it is in line with the arguments of Alkebäck and Hagelin (2004) that daily returns are poor measures of how futures expirations impact price volatility.

More clear-cut results come from the analysis of volatility measure based on maximal and minimal prices. The return volatility VOL_t of single stocks on expiration days is significantly higher than on the control days. In the case of index futures, the application of this measure does not reveal significant changes. Hence, expiration day effects on volatility are observed only in the case of single stocks.

A high-low estimator of volatility was also employed by Vipul (2005), who stated that on the Swedish equity market neither index futures expirations nor stock futures expirations significantly affected the volatility of underlying assets. However, the key difference between stock futures listed on the WSE and those analysed by Vipul (2005) lies in the settlement procedure. On the Warsaw futures market, the settlement price of stock futures is equal to the last transaction price of the underlying asset, while for OMX stocks it was calculated as the weighted average price from the last half-hour of the trading. The different results obtained for the Polish and Swedish markets seem to confirm the thesis formulated by Chung and Hseu (2008) that, “using an average price settlement based on a longer period would mitigate expiration day effects much better than a closing price settlement”. This is also supported by the lack of volatility effect on WIG20 and mWIG40 as the settlement values of index contracts are based on the average values from the last hour of the expiration day.

Negative values of medians of the close-to-close price reversal measure REV_t in Table 5 computed for WIG20 show that the major index of the WSE does not change its direction after expiration of futures. It is rather the opposite: WIG20 tends to continue and the returns on the day after expiration usually have the same sign as the returns on expiration day. The same observation can be drawn when we restrict attention to overnight returns.

The behaviour of mWIG40 is quite different. The positive mean and median of REV_t indicates a reverse of mWIG40 returns after futures expiration. Moreover, negative values of these statistics for control days deny the existence of this phenomenon on other Fridays under study. Finally, p-values of the Mann-Whitney tests calculated both for the close-to-close and for overnight price reversal measure confirm the significance (at least at the 10% level) of price reversal of mWIG40 implied by futures expirations. Equally strong results, but with more significant differences, can be noticed when changes in prices of single stocks on the day after expiration are analysed. Similar conclusions are also valid for overnight returns. However, we observe a reduction in the differences between means and medians computed for expiration and control days. Additionally, overnight returns of single stocks after the other Fridays under study also tend to reverse their signs, as indicated by non-negative means and medians. Comparison of the results in Panel A and B in Table 5 indicates that price reversal of single stocks and the mWIG40 index is reflected both in close-to-close returns and in overnight returns. Chay, Kim and Ryu (2013) claimed that abnormal price levels caused by futures expiration should revert to the normal level on the following morning. The results from WSE only partially confirm this statement. Although the process of price reversal starts at the opening of the market on the day following expiration, it lasts until the end of the Monday trading session.

The results of the application of classical measures of expiration day effects reported in Tables 3–5 can be summarised as follows. Expiration of futures on the WSE significantly increases turnover of all underlying assets except for the mWIG40 index, whereas only the volatility of single stock prices increases. A price reversal effect can be noticed after the expiration of mWIG40 and single stock futures.

4.2 Results from event study analysis

The results in the previous subsection are based on the comparison of prices, volatility and turnover on expiration days with control days only. To describe the impact of futures expiration on the spot market from a different perspective, we apply event study analysis. This allows us to compare the behaviour of prices, volatility and turnover in expiration days with “normal” days from the pre-event window.

The event study analysis is performed for each measure considered in the previous subsection; however, in order to save space we present only the results for log-turnover, relative turnover, volatility measure and overnight returns. The results for WIG20 and mWIG40 are reported in Table 6, where for each variable we present the values of averages together with the values of the test statistic of the τ_{grank} test. However, the results of the analysis of volatility measures are not included in the table as all of them are insignificant.

The leftmost part of Panel A presenting the results for WIG20 contains averages of abnormal log-turnover. The average on a day $t = 0$ is equal to 0.545 and the value of the test statistics indicates a significantly positive (at the 1% level) impact of the event. It confirms the results from the previous subsection that futures expiration increases trading activity on expiration day. Here, log-turnover of WIG20 stocks on expiration days is about 55% higher than usual. On the next day, ($t = 1$) the average -0.262 is significantly negative at the 5% level, which suggests that the day after futures expiration, the activity of investors falls rapidly below its usual level. It is also smaller than activity on the other Monday in the event window ($t = -4$) which also has a significantly negative average. The other averages in the event window are insignificant.

The results of the event study analysis applied to relative turnover (the middle part of Panel A) show significantly positive averages on days $t = 0$, $t = 2$, and $t = -3$ (0.334, 0.2, and 0.188, respectively), and significantly negative averages on $t = 1$ and $t = -4$. This confirms the observations made on the basis of log-turnover that trading activity on expiration significantly increases (much more than expected) and then significantly decreases on the next day. The drop in the trading activity the day after expiration is so huge that the return back to its normal level on the next day is seen as a significantly positive change.

Significant changes for $t = -3$ and -4 suggest a periodic pattern in investors' trading activity as $t = -3$ and $t = 2$ are usually Thursdays and $t = -4$ and $t = 1$ are usually Mondays. However, the values of $\overline{ARU_t}$ for Mondays are very different from each other, indicating a strong impact of futures expiration on trading activity on the next day. On the other hand, the averages for Thursdays are very close, which indicates periodicity rather than the impact of expiration.

The other measures mentioned in Subsection 4.1 have insignificant averages around the event. In particular, there are no significant changes in any of the volatility measures for WIG20. Also, price reversal after expiration is not detected, which is reflected in the right part of Panel A of the table.

The results for mWIG40 futures in Panel B are very similar to those of WIG20. In contrast to the results based on the classical measures from the previous subsection, they clearly confirm the effect of increased turnover values of mWIG40, but do not confirm the effect of price reversal. On futures expirations, log-turnover values of the index are higher than expected as the average of abnormal log-turnover, $\overline{AV}_0$ is significantly positive. Moreover $\overline{AV}_1$ is significantly negative at the 5% level, which is a sign of reduced investors' activity after expiration.

On the other hand, day to day changes in trading activity are insignificant on the expiration day, but the changes in log-turnover in the two days after the expiration are similar to those in WIG20: the drop in turnover on the next day is greater than expected, and then its return back is also significantly stronger than usual.

The price reversal effect in Table 6 is analysed separately in two clusters according to the value of abnormal return AR_0 where the return R_0 is a log-return from open to close on the expiration day. In addition to this analysis, we study the price reversal effect when events are classified into respective clusters by abnormal daily close-to-close returns. In that case, averages of abnormal overnight returns before the expiration day are significant and their signs are in line with signs of close-to-close abnormal returns on the expiration day. This means that significant abnormal changes of indexes on the expiration day start the night before it. However, even in that classification means $\overline{AR_t'^{co}}$ remains insignificant on the day after the expiration.

The lack of the significant price reversal implied by mWIG40 futures expiration is due to the fact that in the event study analysis we define price reversal in a different way than in the analysis of classical measures. The results in Table 5 indicate that after futures expirations the changes of the sign of mWIG40 returns occur more often than its continuation. However, Table 6 shows that the returns on the day after expiration do not deviate from their expectations as the average of abnormal overnight returns $\overline{AR_t^{co}}$ is insignificant and even has the same sign as abnormal open-to-close returns on expiration. The analysis of abnormal close-to-close returns (not presented in the table) leads to an analogous conclusion. This example allows us to notice the limitation of the price reversal measure defined by Stoll and Whaley (1986). As was noticed by Vipul (2005), the measure skips information about the magnitude of total change, while this change can be negligible both from the investors' and regulators' point of view.

The last part of the event study analysis is conducted on turnover values and returns of individual stocks. Table 7 confirms the existence of all three expiration day effects under study. As for WIG20 and mWIG40, significantly positive $\overline{AV_0}$ confirms that expiration of single stock futures increases turnover of underlying assets on the expiration day above its expected level. Surprisingly, not only average daily abnormal turnover values are significantly positive for $t = 0$, but also for $t = -1$. This is evidence that trading on these assets increases significantly the day before expiration and remains high on the day of expiration. It is worth mentioning that the volume effect is the most pronounced for single stocks where the value of $\overline{AV_0}$ is visibly higher than the values for WIG20 and mWIG40. However, similarly to both the indexes, activity of investors diminishes after futures expiration, but this decline is significant at the 5% level. Let us note here that the application of trading volume instead of turnover value leads to the same conclusions.

Instead of reporting the results of the event study for relative turnover, which are similar to the results for indexes, we present in Table 7 the analysis of volatility effects, which shows significantly increased volatility of stock prices only on the expiration days. Due to simulations from Section 3.2 and the application of empirical critical values, we must consider $\overline{AVOL_{-1}}$ as insignificant.

The right-hand side of Table 7 confirms the existence of single stock prices reversion. This is when prices on an expiration day increase more than usual, then before the opening of the next session they fall significantly (at the 5% level) below their expected levels. The change after negative abnormal returns on expiration days is insignificant. These results supplement observations from Table 5. An interesting feature that can be observed in Table 7 is significantly positive $\overline{AR_0^{co}}$ for $AR_0 > 0$. It indicates that expiration days when stock prices fall more than usual are preceded by nights with unusually high increases.

The results from the event study analysis presented above show even more clearly than results based on classical measures that expiration day effects are much stronger in the case of single stock futures than in the case of index futures. It is in line with Chung and Hseu's (2008) opinion that the effects are particularly strong when the settlement price of the contract is based on the closing price of an underlying asset.

4.3 Evolution of expiration day effects on the WSE

In order to examine how the impact of futures expirations on stocks on the WSE was changing in the period under study, we repeat the above analysis for single stock futures in various sub-periods. To ensure adequate power of tests and comparability of results, we decided to divide the whole period of 2003–2016 into four sub-periods with a similar number of events under study in each, as follows: 2 January 2003 – 31 December 2009; 2 January 2010 – 14 April 2013; 15 April 2013 – 31 May 2015; and 1 June 2015 – 31 December 2016.

The comparison of turnover and relative turnover reported in Table 8 confirms the existence of volume effect in each of the sub-periods. Turnover on expiration days is significantly higher than on both kinds of control days. What is more, positive means and medians of the relative turnover in the right panel of Table 8 indicate that trading activity on expiration days is higher than on the day before. That change is significantly stronger than in the case of the other Fridays under study, when usually the drop in turnover and negative relative log-turnover is observed. The strongest change of the log--turnover on expiration days is observed in the second sub-period (January 2010 – April 2013), where the average of RV_t equals 0.781. These volume effects in each of the sub-periods are in line with the previous results from Table 3.

The application of the event study analysis (presented in Table 9) also confirms the very strong and persistent impact of single stock futures expiration on the turnover of underlying stocks. Averages $\overline{AV}_0$ are significantly positive in each sub-period. Their highest values (0.913 and 0.919) are observed between 2010 and 2015. Comparison of these values with the average log-turnover from the left-hand side of Table 8 leads to the conclusion that futures expiration doubles the turnover value of single stocks. In general, the averages $\overline{AV}_t$ are positive a few days before expiration and are negative on the next day. Besides these common features, some differences in changes of log-turnover in sub-periods are also observed. First, the drop in the trading activity on Mondays after expiration is significant only in the first two sub-periods (2003–2013). On the other hand, in the third sub-period (2013–2015) a significant abnormal increase in turnover is observed on the day before expiration. Other averages of abnormal log-turnover in the event windows are insignificant. This indicates that the total turnover of stocks with futures contracts does not change significantly in the week before expiration, except for the two cases described above.

Event study analysis performed for relative log-turnover (not presented here) confirms the results obtained in the case of log-turnover itself. In each sub-period, averages of abnormal relative turnover on expiration are significantly positive, whereas on the next day they are significantly negative. In the first two sub-periods, significantly positive averages are also observed two days after expiration. On the other hand, in the third sub-period (2013–2015) significantly positive abnormal change in trading activity appears on the day before expiration. This last result is in line with the observation made on the basis of results from Table 9 that in this period turnover increases significantly already on day $t = -1$.

Results in Panel B of Table 4 only partially indicate increased volatility of stock prices during trading sessions. Deeper analysis of this issue (Table 10) reveals that only in the third sub-period are absolute values of open-to-close returns on expiration significantly higher than on control days. In the other sub-periods, these differences are insignificant (1st and 2nd sub-period) or have the wrong sign (comparison with control days I in the fourth sub-period). A similar conclusion can be drawn from the analysis of volatility measures based on minimal and maximal values of stock prices during a trading session VOL_t. However, in that case, a significant difference is also observed in the 2nd and 4th sub--periods when comparison is made with control days II (i.e. with third Fridays of months without futures expiration).

Due to the significant impact of expiration on volatility measured by VOL_t, further event study analysis is performed on that measure. As a result, in Table 11 a very strong impact of futures on volatility on spot market in the 2013–2015 period is also visible. In that period $\overline{AVOL}_t$ is significantly positive on expiration day as well as the day before. Significant $\overline{AVOL}_0$ is also observed in the second sub-period.

The results of the research on the price reversal effect in the sub-periods are presented in Table 12. In the first sub-period, stock prices tend to continue after expiration rather than reverse their direction. The average of REV_t, a reversal measure based on close-to-close returns after expiration, is negative (similar to averages on control days). On the other hand, when only overnight returns are applied, the average is positive. It suggests that during the night after the expiration, prices slightly change their direction, but even these changes disappear during the next day's trading session. However, price reversal is more pronounced in the next sub-periods. Averages and means of reversal measures on expiration days are positive and they are, in general, significantly greater than the values of the measures on control days. The differences in distribution of reversal measures on expiration and control days are significant particularly in the third sub-period. Prices reverse during the night after expiration, and then this change is amplified during the next trading session. In the second and fourth sub-periods, the overnight change of price direction is too weak to be significantly greater than on control days, but it begins the process which results in a significant change on the close of the next day.

Because we are mainly interested in an immediate change in price direction, in Table 13 we present results of event study analysis for overnight returns only. As before, we divide them into two clusters according to the value of abnormal price change during the session on an expiration day. As before, price reversal effects are visible mainly in the second and third sub-periods. In both cases $\overline{AR}_1^{co}$ s after $AR_0 > 0$ are significantly negative, which is in line with the results from Table 7.

The analysis of an expiration day effect conducted in the sub-periods reveals that regardless of the period of time, expiration of stock futures involves intensified activity of investors reflected in increased turnover value of underlying stocks. On the other hand, price effects like increased volatility and price reversal were especially strong between 2010 and 2015. The lack of these effects in the first of the examined sub-periods can be explained by the fact that stock futures were just being launched into the market. New and complex financial products had low liquidity and were not used in arbitrage strategies and speculations as often as in the following years. In 2015, between the third and fourth sub-periods, there is a clear-cut change in the occurrence of price effects of single stock futures expirations. Strong price effects seem to disappear after the introduction of changes in the short selling regulations. This conclusion is in line with the findings of Alkebäck and Hagelin (2004) and Debasish (2010), who also found that when the restriction of short selling has been lifted, price effects of futures disappear. This confirms the hypothesis that easy access to short selling lessens the impact of futures expiration on stock prices.

5 Summary and conclusions

There are three expiration day effects analysed in the recent literature that are most noticeable: increased turnover value, increased volatility, and price reversal after expiration. To study the existence of these effects on the Warsaw Stock Exchange, two methods were applied: event study analysis and comparison of various measures computed on expiration and on control days.

This study confirms the hypothesis formulated in Subsection 3.3 regarding the existence on the WSE of strong volume effects. Investors' trading activity on expiration days is significantly higher than its usual level. It is also higher than on third Fridays of months without futures expirations and on other Fridays from the expiration months. These significant results are valid when indexes WIG20 and mWIG40, as well as single stocks, are considered. However, the strongest changes in trading activity are observed in the case of single stocks, because they occur even on the day before the expiration.

As supposed in Subsection 3.3, the other expiration day effects, namely volatility effects and price reversals, are visible only in the case of single stocks. Their existence is confirmed by both analysis methods. The most interesting is, of course, how expiration of futures impacts stock prices. This study shows that, on average, stock prices tend to reverse after futures' expiration and the change of their directions is reflected both in close-to-close and in overnight returns. However, event study analysis reveals that overnight returns after expiration day differ significantly from their expected values only when prices on expiration are higher than expected.

Additional analysis in the sub-periods reveals that the strongest expiration day effects were observed between 2010 and 2015. Then, after the introduction of changes in the rules regarding short sale in May 2015, these effects diminished.

The results of the paper are mostly compatible with the foregoing studies on this topic conducted by Morawska (2004, 2007) and Suliga (2017). Only the effect of increased volatility in WIG20 returns detected by Morawska (2007) is not confirmed. The potential source of this difference is that Morawska studied expirations effects only on the basis of data from the initial period of the futures market on the WSE between December 2002 and June 2006.

There are a few reasons for the differences in the expiration day effects between single stocks and indexes, but the final settlement procedure of futures seems to be one of the most important factors. The settlement price of single stock futures is equal to the price of the stock from the last transaction on the expiration day. On the other hand, the final settlement price of index futures is calculated on the basis of the index value from the last trading hour and the value at the close. Thus, it is much easier to influence the price of the stock on market close than to influence the average return of the index from the last hour of trading. Moreover, to carry out an arbitrage strategy with opened positions on stock futures, it is sufficient to place market-on-close orders on expiration days. Index arbitrage, which is intrinsically much more expensive than arbitrage on stocks, is additionally constricted by an effective futures' settlement procedure.

The occurrence of expiration day effects of stock futures raises the question about the need to make changes in the way of calculating final settlement prices of these contracts. Chung and Hseu (2008), on the Singapore and Taiwan futures exchanges, as well as Hsieh and Ma (2009) on the Taiwan futures exchange, verify that average price settlement is much better than closing settlement. Also, Xu (2014) states that the desirable solution to reduce adverse expiration day effects is 'to adopt a long settlement period with an average price settlement procedure'.

The analysis of the expiration day effects conducted in the sub-periods shows that the adverse impact of stock futures on the spot market has decreased over time. It seems that the introduction of new rules of short sale have reduced price effects of stock futures expirations, and hence the changes in settlement procedure are not necessary. However, further study on this topic with the use of high-frequency data should be carried out to clearly confirm this hypothesis.

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Appendix

Table 1
The list of futures included in the research

First expiration	Underlying asset (abbreviation)	Number of expiration days
Jun 13, 2001	WIG20	64
Mar 15, 2002	mWIG40	60
Mar 21, 2003	KGH, PEO, PKN	56
Jun 20, 2003*	BZW	24
Jun 20, 2003**	MIL	17
Sep 16, 2005	PKO	46
Jun 18, 2010	ACP, PGE, PGN	27
Dec 17, 2010	PZU	25
Mar 18, 2011	TPE	24
Jun 26, 2011	LTS	23
Sep 16, 2011	CDR	22
Dec 16, 2011	JSW, LWB	21
Dec 16, 2011	KER	15
Dec 16, 2011	GTC	14
Mar 16, 2012	GPW	20
Sep 21, 2012	SNS	17
Jun 15, 2012	BRS	12
Mar 21, 2014	OPL	12
Mar 21, 2014	ALR	9
Dec 18, 2015	ENA	5
Dec 18, 2015	CCC, CPS	4
Dec 16, 2016	ATT, CIE, ING, KRU, MBK	1

* Markings of futures on BZW were suspended in December 2008 and restarted in December 2016.
** Markings of futures on MIL were suspended in March 2007 and restarted in December 2015.

Table 2

Rejection rates of test statistics of the null hypothesis of no event effect (in %)

	WIG20			Single stocks		
	1%	**5%**	**10%**	**1%**	**5%**	**10%**
Log-turnover V_t	1.8	6.1	10.4	1.7	6.6	12.9
Relative log-turnover RV_t	1.1	5.1	9.5	1.0	5.2	10.7
Absolute daily returns $\|R_t\|$	1.2	5.6	10.7	1.3	5.7	10.7
Absolute close-to-open returns $\|R_t^{oc}\|$	0.6	4	9.2	1.1	5.5	11.5
Volatility measure VOL_t	1.2	6.2	12.8	1.6	8.2	12.6
Overnight returns R_t^{ON}	0.7	4.8	10.1	1.0	4.3	9.9

Notes:
This Table presents the rejection rates of τ_{grank} test based on 1,000 simulations. In the case of WIG20 clusters of 60 events are randomly generated with replacement from trading days between March 2001 and December 2016. For single stock futures clusters of 30 events are randomly generated with replacement from trading days between March 2001 and December 2016. For each event data of about ¾ of stocks from Table 1 traded on that day are taken into account. Simulation is performed with pre-event window of length 45 (t = -50,…, -6) and the event window of length 8 (t = 5,…, 2). The 95 percent confidence intervals for rejection rates at the 1%, 5%, and 10% are [0.38%, 1.62%], [3.65%, 6.35%] and [8.14%, 11.86%], respectively.

Table 3

Measures of volume effects of futures expirations

	WIG20 futures (61 observations)			mWIG40 futures (60 observations)			Single stock futures (589 observations)		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**	**mean**	**median**	**p-value**
Panel A: log-turnover V_t									
Expiration days	13.787	14.068	–	11.529	11.749	–	10.568	10.775	–
Control days I	13.377	13.473	**0**	11.455	11.571	0.168	9.789	9.837	**0**
Control days II	13.072	13.274	**0**	11.354	11.428	0.106	9.744	9.744	**0**
Panel B: relative log-turnover RV_t									
Expiration days	0.335	0.439	–	0.05	0.13	–	0.590	0.650	–
Control days I	0.068	-0.046	**0**	0.151	0.029	0.239	-0.069	-0.067	**0**
Control days II	-0.15	-0.125	**0**	-0.036	-0.063	**0.022**	-0.11	-0.11	**0**

Notes:
This Table presents the means and medians of two measures of trading activity, namely log-turnover and relative turnover. The measures are computed on expiration days and on two groups of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). Distributions of the turnover measures on expiration and on control days are compared via Mann-Whitney tests. Their p-values are also presented in the Table.

Table 4

Measures of volatility effects of futures expirations

	WIG20 futures (61 observations)			**mWIG40 futures (60 observations)**			**Single stock futures (589 observations)**		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**	**mean**	**median**	**p-value**
Panel A: absolute values of close-to-close returns $\|R_t\|$									
Expiration days	0.984	0.775	–	0.7	0.429	–	1.634	1.217	–
Control days I	1.055	0.886	**0.059**	0.693	0.594	0.205	1.497	1.285	0.244
Control days II	1.038	0.831	0.342	0.677	0.522	0.325	1.426	1.426	0.505
Panel B: absolute values of close-to-open returns $\|R_t^{oc}\|$									
Expiration days	0.878	0.619	–	0.583	0.429	–	1.628	1.352	–
Control days I	0.970	0.807	**0.063**	0.581	0.479	0.249	1.497	1.306	0.857
Control days II	0.984	0.747	0.169	0.704	0.503	0.142	1.406	1.406	**0.051**
Panel C: volatility measure VOL_t									
Expiration days	1.744	1.472	–	1.232	1.03	–	3.204	2.877	–
Control days I	1.719	1.496	0.851	1.06	0.973	0.315	2.894	2.585	**0.009**
Control days II	1.857	1.519	0.566	1.256	1.035	0.865	2.829	2.829	**0**

Notes:
This Table presents the means and medians of three measures of volatility computed on expiration days and on two groups of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). Distributions of the volatility measures on expiration and on control days are compared via Mann-Whitney tests. Their p-values are also presented in the Table.

Table 5

Measures of price reversal effects

	WIG20 futures (61 observations)			mWIG40 futures (60 observations)			Single stock futures (589 observations)		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**	**mean**	**median**	**p-value**
Panel A: close-to-close price reversal REV_t									
Expiration days	0.037	-0.104	–	0.022	0.111	–	0.161	0.187	–
Control days I	-0.205	-0.168	0.296	-0.288	-0.205	**0.045**	-0.236	-0.190	**0**
Control days II	-0.299	-0.15	0.398	-0.24	-0.187	**0.085**	-0.423	-0.178	**0**
Panel B: overnight price reversal REV_t^{ON}									
Expiration days	-0.019	-0.021	–	0.011	0.04	–	0.117	0	–
Control days I	-0.082	-0.097	0.406	-0.108	-0.105	**0.009**	0.011	0.052	**0.031**
Control days II	-0.111	-0.16	0.354	-0.177	-0.113	**0.034**	0.027	0	**0.006**

Notes:

This Table presents the values of means and medians of price reversal measures defined in Section 3.1 based on close--to-close (Panel A) and overnight returns (Panel B). Values of these measures are computed for WIG20, mWIG40 and single stocks mentioned in Table 1 for expiration days and for two kinds of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). The Table also presents p-values of nonparametric Mann-Whitney U test which is employed to verify whether there are significant differences between distribution of the measures on expiration days and control days.

Table 6

Expiration day effects of futures on WIG20 index and futures on mWIG40 returns. Results from event study analysis

t	Volume effect				Price reversal effect			
					$AR_0 > 0$		$AR_0 < 0$	
	$\overline{AV}_t$	τ–grank	$\overline{AVOL}_t$	τ–grank	$\overline{AR}^{co}_t$(%)	τ–grank	$\overline{AR}^{co}_t$(%)	τ–grank
Panel A: expiration day effects of futures on WIG20 index								
-5	0.127	0.214	0.001	-0.142	-0.138	-0.579	-0.137	-1.341
-4	-0.053*	-1.992	-0.181*	-1.821	-0.197*	-1.845	0.055	-0.122
-3	0.136	0.098	0.188**	2.272	-0.109	-0.895	-0.162*	-1.782
-2	0.214	1.361	0.077	0.944	-0.031	-0.24	0.102	0.505
-1	0.21	1.655	-0.005	-0.022	0.015	-0.019	-0.035	-1.659
0	**0.545*** **	**4.671**	**0.334*** **	**3.26**	**0.087**	**0.252**	**0.18**	**0.75**
1	-0.262***	-2.883	-0.808***	-4.917	0.096	-0.019	0.188	0.621
2	-0.062	-0.44	0.200**	2.272	-0.068	-0.58	-0.047	-0.845
n	61		61		33		31	
Panel B: expiration day effects of futures on mWIG40 index								
-5	0.039	-0.655	-0.002	-0.093	-0.044	-0.17	-0.163	-0.562
-4	-0.113**	-2.293	-0.152	-1.206	-0.087	-1.192	0.052	0.041
-3	0.04	-0.69	0.153	1.634	-0.086	-0.702	-0.174	-1.668
-2	0.119	0.689	0.079	1.167	-0.032	-1.045	-0.128	-0.328
-1	0.149	0.902	0.03	0.203	0.01	0.000	-0.004	-0.287
0	**0.192** **	**2.39**	**0.043**	**1.12**	**0.063**	**0.525**	**0.057**	**-0.452**
1	-0.201***	-2.869	-0.393***	-2.837	0.120	1.224	-0.073	-1.07
2	0.001	0.261	0.202***	3.174	0.008	-0.109	-0.023	-0.494
n	59		59		36		24	

Notes:
This Table presents the results of the event study analysis employed to detect the expiration day effect of futures as described in Section 3.2. For each day in the event window starting from the 5th day before expiration and ending on the 2nd day after it, average abnormal: turnover value, volatility and overnight returns are presented with corresponding statistic values. Panel A of the table presents results computed for the WIG20 index, while in Panel B presents the results for the mWIG40.
***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 7

Expiration day effects of stock futures. Results from event study analysis

t	Volume effect		Volatility effect		Price reversal effect			
					$AR_0 > 0$		$AR_0 < 0$	
	$\overline{AV_t}$	τ–grank	$\overline{AVOL_t}$(%)	τ–grank	$\overline{AR_t^{co}}$(%)	τ–grank	$\overline{AR_t^{co}}$(%)	τ–grank
-5	0.027	0.662	0.028	0.61	0.072	0.762	-0.086	-1.233
-4	-0.141	-1.376	-0.049	-0.309	-0.012	-0.862	-0.064	-1.366
-3	0.02	0.736	-0.063	-0.094	-0.143	-2.269	-0.057	-0.978
-2	0.035	0.839	-0.064	-0.095	0.051	0.13	0.023	1.173
-1	0.149**	2.06	0.145*	1.855	0.006	-0.709	0.027	-1.038
0	**0.739*** **	**7.719**	**0.38*** **	**3.949**	**0.037**	**-0.228**	**0.25* **	**1.976**
1	-0.225**	-2.253	-0.111	-0.164	-0.052**	-2.185	0.164	1.167
2	-0.047	-0.17	-0.155	-0.978	-0.109	-1.505	0.02	0.451
n	589		589		313		276	

Notes:

This Table presents the results of the event study analysis employed to detect the expiration day effect of stock futures as described in Section 3.2. For each day in the event window starting from the 5th day before expiration and ending on the 2nd day after it, average abnormal: turnover value, volatility and overnight returns are presented with corresponding τ_{grank} statistic values. For tests of volume and volatility effects, empirical critical values from simulations in Section 3.2 are applied. For the 1%, 5%, and 10% significance levels they are: 2.91, 2.19, 1.68 (for volume) and 2.89, 2.27, and 1.91 for volatility.

***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 8

Measures of volume effects in the sub-periods

	Log-turnover V_t			Relative log-turnover RV_t		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**
	January 2003 – December 2009 (135 observations)					
Expiration days	11.027	11.435	–	0.345	0.436	–
Control days I	10.45	10.865	**0**	-0.098	-0.108	**0**
Control days II	10.478	10.478	**0.001**	-0.131	-0.131	**0**
	January 2010 – April 2013 (156 observations)					
Expiration days	10.941	11.191	–	0.781	0.804	–
Control days I	10.04	9.913	**0**	0.02	0.044	**0**
Control days II	9.879	9.879	**0**	-0.157	-0.157	**0**
	April 2013 – June 2015 (148 observations)					
Expiration days	10.311	10.47	–	0.641	0.656	–
Control days I	9.385	9.293	**0**	-0.098	-0.073	**0**
Control days II	9.209	9.209	**0**	-0.123	-0.123	**0**
	June 2015 – December 2016 (155 observations)					
Expiration days	10.02	9.926	–	0.559	0.527	–
Control days I	9.333	9.227	**0**	-0.113	-0.112	**0**
Control days II	9.282	9.282	**0**	-0.033	-0.033	**0**

Notes:
This Table presents the values of means and medians of log-turnover and relative log-turnover described in Section 3.1. The values of these trading activity measures are computed for WIG20, mWIG40 and single stocks mentioned in Table 1 for expiration days and for two kinds of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). The Table also presents p-values of the nonparametric Mann-Whitney U test, which is employed to verify whether there are significant differences between the distribution of the measures on expiration days and control days.

Table 9

Event study analysis for log-turnover

t	2003–2009		2010–2013		2013–2015		2015–2016	
	$\overline{AV_t}$	**τ–statistics**	$\overline{AV_t}$	**τ–statistics**	$\overline{AV_t}$	**τ–statistics**	$\overline{AV_t}$	**τ–statistics**
-5	-0.113	-0.244	0.127	1.454	0.033	0.571	0.045	-0.069
-4	-0.196	-1.466	-0.232	-1.398	-0.075	-0.4	-0.061	-0.883
-3	-0.035	0.467	0.043	1.043	0.045	0.6	0.022	0.025
-2	0.029	1.244	0.064	1.002	0.045	0.822	0.000	-0.292
-1	0.018	0.981	0.133*	1.693	0.278**	2.516	0.156	0.77
0	**0.363*** **	**4.645**	**0.913*** **	**6.648**	**0.919*** **	**6.042**	**0.717*** **	**5.56**
1	-0.364**	-2.323	-0.246*	-1.685	-0.206	-1.627	-0.096	-1.156
2	-0.082	0.029	-0.054	0.059	-0.107	-0.758	0.051	0.104
n	135		156		148		150	

Notes:

This Table presents the results of event study analysis employed to detect the expiration day effect of stock futures as described in Section 3.2. For each day in the event window starting from the 5th day before expiration and ending on the 2nd day after it, average abnormal turnover value, in sub-periods are presented with corresponding *τ–grank* statistic values. Due to results of simulations in Section 3.2 empirical critical values are applied. For the 1%, 5%, and 10% significance levels they are: 2.91, 2.19, 1.68.

***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 10

Measures of volatility effects in the sub-periods

	$\lvert R_t^{oc} \rvert$			VOL_t		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**
January 2003 – December 2009 (135 observations)						
Expiration days	1.555	1.431	–	3.21	3.003	–
Control days I	1.451	1.324	0.813	2.911	2.77	0.123
Control days II	1.816	1.816	0.146	3.458	3.458	0.732
January 2010 – April 2013 (156 observations)						
Expiration days	1.487	1.138	–	2.988	2.756	–
Control days I	1.437	1.226	0.333	2.847	2.559	0.272
Control days II	1.318	1.318	0.403	2.734	2.734	**0.027**
April 2013 – June 2015 (148 observations)						
Expiration days	1.845	1.375	–	3.471	2.76	–
Control days I	1.262	1.119	**0.043**	2.478	2.401	**0**
Control days II	1.204	1.204	**0.007**	2.474	2.474	**0**
June 2015 – December 2016 (155 observations)						
Expiration days	1.632	1.408	–	3.177	2.88	–
Control days I	1.853	1.486	**0.053**	3.353	2.935	0.22
Control days II	1.321	1.321	**0.088**	2.733	2.733	**0.014**

Notes:
This Table presents the means and medians of volatility computed on expiration days and on two groups of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). The analysis is performed in four sub-periods. The distributions of the volatility measures on expiration and on control days are compared via Mann-Whitney tests. Their p-values are also presented in the Table.

Table 11

Event study analysis for volatility

t	2003–2009		2010–2013		2013–2015		2015–2016	
	$\overline{AVOL}_t$	τ–statistics	$\overline{AVOL}_t$	τ–statistics	$\overline{AVOL}_t$	τ–statistics	$\overline{AVOL}_t$	τ–statistics
-5	-0.208	-1.057	0.213	1.021	-0.107	-0.493	0.181	1.079
-4	-0.291	-1.304	-0.24*	-1.836	0.324	1.301	0	-0.138
-3	-0.085	0.42	-0.057	-0.605	0.099	0.881	-0.209	-0.796
-2	0.043	0.286	-0.3–23	-1.795	0.012	0.447	0.036	0.383
-1	-0.128	0.029	-0.003	-0.364	0.517**	2.483	0.18	1.315
0	**-0.048**	**0.893**	**0.295****	**2.118**	**0.967*****	**3.772**	**0.276**	**1.374**
1	-0.323	-1.21	-0.128	-0.334	0.05	0.549	-0.062	0.123
2	-0.255	-0.868	-0.013	0.053	-0.074	-0.239	-0.295	-1.344
n	135		156		148		150	

Notes:

This Table presents the results of the event study analysis employed to detect the expiration day effect of stock futures as described in Section 3.2. For each day in the event window starting from the 5th day before expiration and ending on the 2nd day after it, average abnormal volatility measures in sub-periods are presented with corresponding *τ–grank* statistic values. Due to the results of the simulations in Section 3.2, empirical critical values are applied. For the 1%, 5%, and 10% significance levels they are: 2.89, 2.27, and 1.91.

***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 12

Measures of price reversal effects in the sub-periods

	REV_t			REV_t^{ON}		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**
	January 2003 – December 2009 (135 observations)					
Expiration days	-0.013	0	–	0.064	0	–
Control days I	-0.171	-0.134	0.59	0.11	0.092	0.819
Control days II	-0.289	0	0.707	0.132	0.112	0.902
	January 2010 – April 2013 (156 observations)					
Expiration days	0.262	0.356	–	0.15	0	–
Control days I	-0.202	-0.029	**0.01**	0.069	0.144	0.903
Control days II	-0.45	-0.244	**0.001**	-0.165	-0.044	**0.029**
	April 2013 – June 2015 (148 observations)					
Expiration days	0.327	0.303	–	0.184	0.031	–
Control days I	-0.215	-0.321	**0.001**	-0.079	-0.015	**0.001**
Control days II	-0.321	-0.24	**0**	0.116	0	**0.067**
	June 2015 – December 2016 (155 observations)					
Expiration days	0.032	0.185	–	0.054	0	–
Control days I	-0.372	-0.306	**0.024**	-0.048	0.038	0.308
Control days II	-0.57	-0.057	**0.051**	0.057	-0.036	0.164

Notes:

This Table presents the values of means and medians of price reversal measures defined in Section 3.1. Values of these measures are computed in sub-periods for single stocks mentioned in the Appendix for expiration days and for two kinds of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). The Table also presents the p-values of the nonparametric Mann-Whitney U test, which is employed to verify whether there are significant differences between the distribution of the measures on expiration days and control days.

Table 13

Event study analysis of price reversal effects

t	2003–2009		2010–2013		2013–2015		2015–2016	
	$\overline{AR_t^{co}}$ (%)	τ–statistics	$\overline{AR_t^{co}}$ (%)	τ–statistics	$\overline{AR_t^{co}}$ (%)	τ–statistics	$\overline{AR_t^{co}}$ (%)	τ–statistics
				$AR_0 < 0$				
-5	-0.352	-1.271	0.096	0.3	-0.255	-1.921	0.102	0.417
-4	0.199	1.312	-0.108	-0.846	-0.017	-0.553	-0.293	-1.515
-3	-0.03	0.205	0.014	-0.017	-0.257	-1.42	0.043	0.178
-2	-0.257	0.026	0.24	1.643	-0.06	-0.309	0.082	0.561
-1	0.051	-0.33	-0.179*	-1.761	0.182	0.294	0.104	-0.107
0	**0.588**	**1.026**	**0.193**	**0.934**	**0.211***	**1.764**	**0.063**	**0.374**
1	0.55*	1.743	0.001	-0.257	0.065	0.325	0.133	0.54
2	-0.2	-0.99	-0.049	-0.39	0.247	1.313	0.058	0.692
n	58		83		70		65	
				$AR_0 > 0$				
-5	-0.038	0.319	0.059	0.119	-0.129	-0.639	0.367	1.605
-4	-0.075	-1.075	-0.128	-0.102	0.012	0.047	0.121	-0.647
-3	-0.235	-1.573	-0.067	-0.967	-0.221	-1.405	-0.053	-0.736
-2	0.052	-0.296	-0.005	-0.003	0.139	0.686	0.019	0.156
-1	-0.147	-0.945	-0.155**	-2.369	0.426*	1.768	-0.101	-0.935
0	**0.053**	**-0.43**	**0.167**	**0.552**	**0.045**	**-0.066**	**-0.096**	**-0.514**
1	0.222	-0.144	-0.296**	-2.399	-0.242**	-2.313	0.083	-0.054
2	-0.176	-1.24	-0.008	-0.329	-0.172	-1.15	-0.077	-0.408
n	77		73		78		85	

Notes:
This Table presents the results of the event study analysis employed to detect price reversal effect of single stock futures in sub-periods. For each day in the event window starting from the 5th day before expiration and ending on the 2nd day after it, average abnormal: turnover value, volatility and overnight returns are presented with corresponding *τ–grank* statistic values.
***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.