„Problemy Zarządzania (Management Issues)"
Vol. 18, No. 4(90), p. 163–177, e-ISSN: 2300-8792
https://doi.org/10.7172/1644-9584.90.9


# Changes in Effectiveness of Delta Hedging Using Options on the WIG20

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Submitted: 08.06.2020 | Accepted: 24.11.2020

**Abstract**

**Purpose:** Based on the research carried out by the author in 2007 and 2015, an increase in the effectiveness of delta hedging with the use of options on the WIG20 was found. The purpose of the study is to compare the results of the 2017–2018 delta hedging effectiveness studies with the results of previous studies, as well as to assess the changes in the effectiveness with an indication of possible causes.
**Design/methodology/approach:** To compare the effectiveness of delta hedging, the estimated Value at Risk was used for unhedged and hedged portfolios in the analyzed periods. The results obtained on the basis of data from the years 2017–2018 were compared with the results for the data from 2007 and 2015.
**Findings:** On the basis of the conducted research, the effectiveness of delta hedging using options on the Polish market can be generally stated, but the durability of the high effectiveness of delta hedging observed in 2015 cannot be stated. In the years 2017–2018, there was a decrease in the effectiveness of delta hedging associated with a significant decrease in liquidity on the option market. The research results highlight the importance of liquidity for the proper option pricing as well as for the possibility of risk reduction.
**Research limitations/implications:** Some difficulty and limitation of the study were quite frequent lack of data regarding the options analyzed in the period 2017–2018.
**Originality/value:** The value of the obtained results is increased by their uniqueness, as changes in the effectiveness of delta hedging on the Polish options market are not discussed in the literature by other authors.

**Keywords:** options, hedging, delta.

**JEL:** G11, G32, O16

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*Suggested Citation*: Węgrzyn, R. (2020). Changes in Effectiveness of Delta Hedging Using Options on the WIG20. *Problemy Zarządzania (Management Issues)*, 18(4), 163–177. https://doi.org/10.7172/1644-9584.90.9.

## Zmiany skuteczności hedgingu delta z zastosowaniem opcji na WIG20

**Streszczenie**

**Cel:** na podstawie przeprowadzonych przez autora badań w latach 2007 i 2015 stwierdzono wzrost skuteczności hedgingu delta z zastosowaniem opcji na WIG20. Celem pracy jest porównanie wyników badań skuteczności hedgingu delta z okresu 2017–2018 z wynikami poprzednich badań, a także ocena zmian skuteczności wraz ze wskazaniem możliwych przyczyn.
**Metoda:** do porównania skuteczności hedgingu delta zastosowano oszacowaną wartość zagrożoną (Value at Risk) dla portfeli niezabezpieczonych i zabezpieczonych w analizowanych okresach. Wyniki uzyskane na podstawie danych z lat 2017–2018 porównano z wynikami dla danych z 2007 i 2015 roku.
**Wyniki:** na podstawie przeprowadzonych badań można ogólnie stwierdzić skuteczność hedgingu delta z zastosowaniem opcji na polskim rynku, ale nie można stwierdzić trwałości wysokiej skuteczność hedgingu delta zaobserwowanej w 2015 roku. W latach 2017–2018 nastąpiło zmniejszenie skuteczności hedgingu delta powiązane ze znacznym spadkiem płynności na rynku opcji. Wyniki badań zwracają uwagę na znaczenie płynności dla właściwej wyceny opcji, a także możliwości ograniczania ryzyka.
**Ograniczenia badań:** pewnym utrudnieniem i ograniczeniem badań były dość częste braki danych dotyczących analizowanych opcji w okresie 2017–2018.
**Oryginalność/wartość:** wartość uzyskanych wyników zwiększa ich unikalność, gdyż zmiany efektywności hedgingu delta na polskim rynku opcji nie są poruszane w literaturze przez innych autorów.

**Słowa kluczowe:** opcje, hedging delta.

## 1. Introduction

The results of previous studies carried out on the basis of data from 2007, and then from 2015, showed an increase in the effectiveness of delta hedging using the WIG20 options (Węgrzyn, 2017). As only two periods were compared, and the changes taking place on the Polish options market may have an impact on the result of hedging, the question of the durability of high effectiveness remained open. In this context, it is justified to conduct further studies allowing a more complete assessment of changes in the effectiveness of this type of hedging.

The purpose of the paper is to compare the results of the research on the effectiveness of delta hedging with the use of the WIG20 options for the period 2017–2018 with the results of previous studies, as well as to assess changes in the effectiveness and indicate possible causes. The estimated Value at Risk for unhedged and hedged portfolios in subsequent research periods was used to assess the effectiveness of hedging.

The basic research hypothesis assumed still high effectiveness of delta hedging related to the specific level of development of the Polish options market. This hypothesis was verified by comparing the effectiveness of delta hedging resulting from the studies for the period 2017–2018 with the effectiveness determined in the previous studies.

https://doi.org/10.7172/1644-9584.90.9

Selected European call options on the WIG20 index, traded on the Warsaw Stock Exchange, were analyzed in detail. The analysis used the data on options, the WIG20 index and the estimated call option deltas provided by the stock exchange.

## 2. Literature Review

Option hedging can be divided into static and dynamic hedging. Static hedging consists in constructing the hedged portfolio and holding it until the expiry date of the option, while dynamic hedging – in constructing the hedged portfolio and its further regular reconstruction (rebalancing) during the hedging period. In dynamic hedging, hedging the portfolio consisting of the underlying instrument and options involves reconstructing the portfolio in such a way that changes in the price of the underlying instrument (share, index) are compensated by changes in the prices of the options. The so-called Greek coefficients are used for the proper construction of the portfolio (Spremann, 1991; Haugen, 1996; Jarrow & Turnbull, 2000; Chance, 2004; Weron & Weron, 2005). The most important Greek coefficients in the context of hedging a portfolio are delta, gamma and vega, as they relate to the main risk factors of such a portfolio – the price of the underlying instrument and its volatility (Alexander, 2008a).

The basic type of dynamic hedging is delta hedging, which consists in using the delta coefficient to define the portfolio structure. This type of hedging protects against small changes in the price of the underlying instrument. The delta coefficient is a measure of the sensitivity of option value to changes in the price of the underlying instrument and it is interpreted as a change in the value of option per unit change in the price of the underlying instrument (Tarczyński, 2003; Weron & Weron, 2005; Jajuga & Jajuga, 2006; Jajuga, 2009).

Delta coefficients can be determined according to the Black-Scholes-Merton model on the basis of the following formula:

$$\delta = e^{-yT} N(d_1),$$

$$d_1 = \left[\ln(S/K) + (r - y + 0.5\sigma^2)T\right] \big/ (\sigma\sqrt{T}),$$

where: $S$ – spot price of the underlying instrument, $K$ – strike price of the option, $T$ – residual time to maturity (in years), $r$ – risk-free interest rate (in annual term), $y$ – dividend yield (in annual term), $s$ – volatility of the underlying instrument (standard deviation of the rate of return on the underlying instrument) (in annual term), $N(\cdot)$ – standard normal distribution function, $e$ – constant.

Since the delta for call options is positive in the range (0; 1), and negative for the put option in the range (-1; 0), to get the delta for the entire portfolio equal to zero, appropriate positions should be taken with regard to the specific options.

The delta coefficient for the entire portfolio can be defined as:

$$Delta_P = n_0 + n_1 Delta = 0,$$

where: $n_0$ – number of underlying instruments, $n_1$ – number of options, *Delta* – option delta coefficient. The underlying instrument delta is 1.

On the basis of the presented equation, it can be stated that, for example, to hedge a buy position on the underlying instrument ($n_0 > 0$) requires taking a sell position ($n_1 < 0$) on an appropriate number of call options ($Delta > 0$) or a purchase position ($n_1 > 0$) on an appropriate number of put options ($Delta < 0$). As the price of options fluctuates less than the price of the underlying instrument, the number of option positions should be correspondingly larger (Alexander, 2008a).

From a theoretical point of view, the effectiveness of delta hedging actually underlies the Black-Scholes model. F. Black and M. Scholes (1973) as first pointed out that the position of the share purchase and the short call position can create a risk-free hedged portfolio (at a given time). They further assumed that since such a portfolio is risk-free, the arbitrage ensures that the return on that portfolio must be at the risk-free interest rate (the arbitrage portfolio concept). By linking this equilibrium condition to the appropriate boundary conditions (arbitrage constraints), F. Black and M. Scholes were able to obtain an accurate analytical model that determines the value of the European call option.

In their considerations, however, some authors emphasized that the unfulfilled assumptions of the Black-Scholes model mean that if Greeks calculated on its basis are used for hedging, certain changes in the value of the hedged portfolio will still occur (see: Avellaneda, Levy, & Paras, 1995; Gupta, 1997).

C. Alexander and L.M. Nogueira (2007) in their paper presented, among others, delta hedging results. In their research, they used data from the US market for the period from January 16, 2004 to June 15, 2004 concerning European call options on the S&P500 index. The synthetic results of hedging using the delta from the Black-Scholes model when adjusting the hedged portfolio daily were as follows: for delta hedging the mean of hedging errors was 0.1401 and the standard deviation was 0.7451.

D. De Giovanni, S. Ortobelli and S. Rachev (2008) in their paper implemented dynamic delta hedging strategies based on several option pricing models. Their data consisted of S&P500 daily (and weekly) returns from January 1, 1995 to January 31, 1998. They compared dynamic hedging strategies obtained with the classical Black-Scholes model with several

https://doi.org/10.7172/1644-9584.90.9

subordinated models. They found that all models forecasted the exposure positions well enough, but the Laplace model, the Student model and the Stable model presented the best performance among all the models considered.

In turn, C. Alexander and A. Kaeck (2011) conducted research for the period from January 2, 2002 to December 31, 2008, but using a different approach consisting in adjusting the delta and gamma from the BSM model, taking into account the sensitivity of the implied volatility to the future price of the underlying instrument. In their research, they used data from the Euronext-LIFFE (*London International Financial Futures Exchange*) on options on the FTSE100 index. Based on the results, they concluded that, in terms of standard deviation, delta-gamma hedging based on the coefficients from the BSM model is better than delta hedging. However, it should be noted that in their research they used the put options, motivating their choice with greater liquidity of these options in relation to the call options.

Overall, however, the mainstream of research has been focused on finding solutions that would enable the greater effectiveness of delta hedging. These efforts have concentrated mainly on the different ways of defining the so-called minimum variance (MV) delta. The MV delta takes account of both the price changes and the expected change in volatility conditional on the price change. To calculate the MV delta, it is necessary to use the model to determine the expected change in the option price arising from both the change in the underlying asset and the associated expected change in its volatility. A number of researchers have implemented stochastic volatility models and used the models' assumptions to convert the basic delta to an MV delta.

For example, I. Casas and H. Veiga (2020) in their paper evaluated the application of two asymmetric stochastic volatility (ASV) models to option price forecasting and dynamic delta hedging. The models ware specified in discrete time in contrast to the classical stochastic volatility models used in option pricing. Using the S&P MidCap 400 and S&P500 European call option quotes, the results showed that volatility asymmetry benefits the accuracy of option price forecasting and hedging cost effectiveness in the large-cap equity sector. However, ASV models do not improve option price forecasting and dynamic hedging in the mid-cap equity sector.

On the other hand, some authors noted that the MV delta is the Black-Scholes delta plus the Black-Scholes vega times the partial derivative of the expected implied volatility with respect to the underlying price. For example, C. Alexander, A. Rubinov, M. Kalepky, S. Leontsinis (2012) introduced several regime-dependent smile-adjusted deltas and compared their effectiveness with the simple smile-adjusted deltas. Using 16 years of daily option prices, out-of-sample hedging performance tests for options of all moneyness and maturities and daily, weekly, or fortnightly rebalancing showed that even the simplest regime-dependent smile-adjustment consistently outperformed implied BSM delta hedging and local volatility and minimum variance smile-adjustments. Markov-switching deltas offered the best performance, with delta-hedging errors often half the size of implied BSM hedging errors.

J. Hull and A. White (2017) pointed out that their paper is similar in spirit to papers such as those by Crépey (2004), Vähämaa (2004) and Alexander et al. (2012). Their paper determined empirically a model for the MV delta. They chose the options on the S&P500, the S&P100, the DJIA, the individual stocks underlying the DJIA, and five ETFs. The research period was January 2, 2004–August 31, 2015 except for the commodity ETFs where data was first available in 2008. Using their concept and the data on options on the S&P500, they showed that it is an improvement over stochastic volatility models, even when the latter are calibrated afresh each day for each option maturity.

In turn, X. Yu, Z. Wang and W. Xiao (2019) stated in their study that the linear hedging of the options ignores the characteristic of a nonlinear change of option prices with respect to the underlying instrument. Their paper established the nonlinear hedging strategy following the study by J. Hull and A. White (2017) to investigate the effectiveness in the case of the Shanghai Stock Exchange 50 ETF options. The results showed that the nonlinear hedge on the Chinese option market is less effective than on the U.S. option market because of short history and lower activity of this market.

Extensive considerations regarding the improvement of delta hedging, as well as the application of the model-free delta and the market delta concept on the Polish options market can be found in the publication by Węgrzyn (2013).

However, the purpose of this paper is not to confirm the effectiveness of delta hedging or to evaluate another approach in this regard. In this case, it is about comparing the effectiveness of delta hedging on the Polish options market in different research periods. The author has not found current foreign publications in this area because, as previously shown, the mainstream of research focuses on finding new solutions, and the research mainly concerns developed markets with high liquidity. Apart from the previously mentioned paper (Węgrzyn, 2017), it seems that no such results concerning the Polish options market have been published so far.

When it comes to the role of the derivatives market in stimulating economic growth, discussed later in this paper, many research results indicate a positive relationship between the development of the derivatives market and economic growth. One of the latest publications on this subject is an article from 2016 (Aali-Bujari, Venegas-Martínez, & Pérez-Lechuga, 2016). This article assesses the impact of derivative markets on economic growth in the world's six largest economies (European Union, United States, Japan, China, India and Brazil) in 2002–2014. The main

https://doi.org/10.7172/1644-9584.90.9

empirical findings based on the dynamic panel data model indicated that derivative markets in these countries had a positive impact on economic growth. In turn, on the Polish market, studies were carried out on the impact of the use of derivatives on the company's value in 2008–2011 (Mizerka & Stróżyńska, 2014). A panel data regression analysis made it possible to capture the positive impact of the use of derivatives on the company's value, with the simultaneous impact of the company's financial characteristics.

## 3. Analysis of Changes in Effectiveness of Delta Hedging

The effectiveness of delta hedging can be measured in a number of ways. In the literature, among the measures of hedging effectiveness, there are measures based on two time points and on time series. The first group includes: dollar offset ratio, Schleifer-Lipp modulated dollar offset, Gürtler effectiveness test, while the second group includes: measures based on linear regression analysis – where the regression coefficient, intercept and determination coefficient $R^2$ are assessed, variability-reduction measure and adjusted hedge interval test (Hailer & Rump, 2005). Among those mentioned, the use of linear regression analysis deserves particular attention, although three quantities are assessed in this approach, which makes comparisons difficult.

Therefore, to facilitate the comparison of the effectiveness of hedging in the analyzed periods, the risk measure in the form of Value at Risk (VaR) was used, calculated for unhedged and hedged portfolios. The comparison of the VaR of these portfolios makes it possible to clearly determine the effectiveness of hedging. Historical VaR in terms of value can be defined as the α-quantile of the empirical income distribution. When calculating the VaR in percentage terms from 1-day rates of return, the 1-day VaR is the α-quantile of the empirical distribution of these rates. VaR compared for the indicated research periods was determined on a 1-day scale, but with some simplification, it can be scaled for a longer period using the square root formula (Alexander, 2008b).

When estimating VaR for the 1% quantile, the sample size should be at least 2,000 daily observations. In the conducted studies, 124 daily observations were obtained for the data from 2007 and 2015, while for the data from 2017–2018, 341 observations were obtained. However, in the case of small research samples or calculating extreme quantiles, a continuous distribution can be fitted to the empirical distribution, which increases the reliability of the results. Such a continuous distribution can be, for example, the Johnson distribution, which is appropriate when the rates of return have a skewed or leptokurtic distribution. 100α% h-daily historical VaR from the Johnson SU distribution is:

$$VaR_{h,\alpha} = -\lambda \sinh\left(\frac{z_\alpha - \gamma}{\delta}\right) - \xi$$

where: $\xi$ – the location of the distribution, $\lambda$ – the scale, $\gamma$ – the skewness, $\delta$ – the kurtosis, sinh – the hyperbolic sine function, $z_\alpha$ – standard normal quantile: $z_\alpha + \Phi^{-1}(\alpha)$ (Alexander, 2008b).

In the analyzed case, due to relatively small samples, the Johnson SU distribution was fitted to empirical distributions, using the algorithm proposed by H. Tuenter (2001) to estimate the parameters. On the basis of the first four moments of the return rates from the portfolios, the parameters for Johnson SU distributions were estimated, and then the appropriate VaR levels were calculated.

In the conducted research, it was assumed each time that a market participant hedged a portfolio of shares corresponding to the WIG20 index with a call option. At the beginning, it defined the composition of the portfolio, which it modified at the end of each session on the basis of each time calculated participation of appropriately selected options. Call options were used to hedge with the strike price closest to the current level of the WIG20 index and with the closest expiry date. Such options are in practice the most liquid.

The research covered a total of three periods: July 2, 2007 – December 28, 2007, July 1, 2015 – December 29, 2015 and January 2, 2017 – December 27, 2018. The WIG20 index options quoted in these particular periods were used in delta hedging. These were call options with different strike prices adjusted to the levels of the WIG20 index and with different expiry dates.

The delta coefficients calculated by the Warsaw Stock Exchange in accordance with the Black-Scholes-Merton model were used to determine the share of the index and individual options in the portfolio. The research assumed that the share of the index in the portfolio did not change, and the share of options was defined as the reciprocal of the delta coefficient. In this case, what should also be remembered is the multiplier in relation to the index and option course expressed in points, which is 10 PLN/point. For detailed calculations, data from the Warsaw Stock Exchange on the option prices and WIG20 index levels were used.

To determine the effectiveness of delta hedging, daily percentage changes in the value of hedged and unhedged portfolios were calculated, and then the Johnson SU distribution was fitted to the empirical distributions of these changes, on the basis of which the relevant VaR was estimated. The calculation results for the data from individual research periods are presented in Table 1. These results for 2007 and 2015 are in line with the results presented in the article from 2017 (Węgrzyn, 2017) in Table 3.

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| Quantile | Unhedged portfolio | | | Hedged portfolio | | |
|---|---|---|---|---|---|---|
| | 2007 | 2015 | 2017–2018 | 2007 | 2015 | 2017–2018 |
| 1% | 3.81% | 4.27% | 1.93% | 2.08% | 2.06% | 0.69% |
| 2% | 3.30% | 3.42% | 1.67% | 1.76% | 1.54% | 0.57% |
| 3% | 2.99% | 2.95% | 1.50% | 1.57% | 1.26% | 0.49% |
| 5% | 2.59% | 2.38% | 1.29% | 1.33% | 0.95% | 0.40% |
| 10% | 2.00% | 1.66% | 0.95% | 0.99% | 0.57% | 0.28% |

*Tab. 1. Johnson VaR estimates. Source: Own study.*

Based on Table 1, it can be concluded that for the given quantiles, the risk of the hedged portfolio is in each case significantly lower than the risk of the unhedged portfolio in a given research period. In order to facilitate the comparison of the effectiveness of delta hedging in particular research periods, after estimating for selected quantiles of Johnson VaR, the differences between the VaR for hedged portfolios and the VaR for unhedged portfolios were calculated, which are presented in Table 2. These differences are a measure of the effectiveness of delta hedging and can be interpreted as changes, expressed in percentage points, in the risk level due to the hedging applied.

Based on the results in Table 2, it can be concluded that for the given quantiles, the effectiveness of delta hedging, measured by changes in VaR, in 2007 was over 1 percentage point. The effectiveness was higher for the lower quantiles. When assessing the overall effectiveness of hedging in this case, it is worth adding that the VaR expressed as a percentage can be converted into a value form by multiplying it by the current value of the portfolio. Therefore, if the value of the portfolio is, for example, PLN 250,000, then with the effectiveness of delta hedging at the level of 1 percentage point, the application of hedging reduces the 1-day VaR by PLN 2,500.

| Quantile | Effectiveness of delta hedging (in percentage points) | | |
|---|---|---|---|
| | 2007 | 2015 | 2017–2018 |
| 1% | -1.73 | -2.22 | -1.24 |
| 2% | -1.54 | -1.88 | -1.10 |
| 3% | -1.42 | -1.69 | -1.01 |
| 5% | -1.26 | -1.43 | -0.89 |
| 10% | -1.01 | -1.09 | -0.67 |

*Tab. 2. Differences in VaR levels for hedged and unhedged portfolios. Source: Own study.*

The results for the 2015 data indicate even greater effectiveness, which can be clearly seen especially with the lower quantiles. However, the results obtained for the data from 2017–2018 are somewhat surprising. On their basis, it can be concluded that the effectiveness of delta hedging in this period was the lowest among the analyzed periods. An attempt to determine the causes of this situation is presented in the next part of this paper.

## 4. Reasons for Changes in Delta Hedging Effectiveness

Comparing the results for the 2015 data with the results for 2007, the main reason for the greater effectiveness of delta hedging is the qualitative changes that took place on the Polish options market. Between these research periods, a new transaction system UTP (*Universal Trading Platform*) was introduced to the Warsaw Stock Exchange, which allows for placing orders generated automatically. The possibility of using the so-called algorithmic trading is very important in the arbitrage activities of market participants, and these contribute to the proper pricing of options. In the conducted research (Węgrzyn, 2016) on changes in the deviations of option prices from specific relationships resulting from the arbitrage, it was found that the number of such deviations has clearly decreased, and, more importantly, the scale of deviations has decreased significantly. The smaller scale of deviations means a greater degree of fulfillment of the assumptions of the Black-Scholes-Merton option pricing model and thus better conditions for its application. In turn, the delta coefficients used in the research on the effectiveness of hedging were coefficients estimated on the basis of this model. The increase in the effectiveness of hedging with the use of these coefficients may therefore result from a better fit of the applied model to reality.

Important determinants of the arbitrage activities also include the level of transaction costs and the possibility of applying the so-called short selling. In the compared periods, along with the development of the options market, it seems, there was a slight reduction in transaction costs, and increased flexibility in the use of short selling, which could also contribute to the increase in the effectiveness of hedging. In addition to the factors indicated, in 2015 there was slightly higher liquidity in the options market compared to 2007. In 2007, the volume of trading in options on the Warsaw Stock Exchange was nearly 400 thousand, and in 2015 it was higher by approximately 40 thousand.

When referring to the decrease in the effectiveness of delta hedging in 2017–2018, attention should be paid primarily to the changes in liquidity on the Polish options market. Relatively low liquidity is a factor that can cause a variety of abnormal price behavior, and it certainly makes it difficult to apply different option strategies, especially the more complex ones that

https://doi.org/10.7172/1644-9584.90.9

require a greater number of options. Additionally, it is also a factor in increasing the spreads used by market makers. The size of the spreads is even treated as a measure of liquidity. An increase in spreads, on the other hand, worsens the hedging possibilities due to the option prices deviating from the model prices.

In order to assess the evolution of liquidity, Figure 1 presents the volume of trading in WIG20 options in the years 2003–2018. Based on this figure, it can be concluded that the trading volume grew rapidly in 2003–2007. In 2008, there was a slight decrease related to, as can be assumed, the beginning of the financial crisis. In 2009–2011, however, a further rapid increase in volume continued. In 2012, as in the case of the entire global derivatives market, there was a decline in the volume of the WIG20 options trading. After the collapse in 2012, however, this volume decreased, with the exception of 2013, also in the subsequent years until 2018. Thus, the volume in 2015 was only slightly higher than the volume in 2009, and in 2017–2018 , so in the last research period, it dropped to the level similar to 2005–2006. In the case of the global market, the total volume of the exchange-traded options increased after a periodic decrease and in 2018 it approached the level from 2011. This was due to, among others, a very strong increase in the volume of trading in currency options, but also an increase in the volume of trading in index options, which in 2017–2018 was 22% and 34% respectively, compared to the previous year.

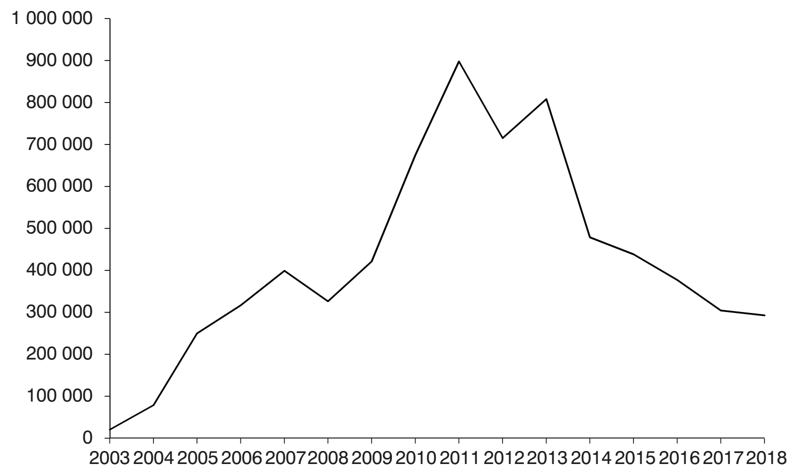


*Fig. 1. The volume of trading in options on the Warsaw Stock Exchange. Source: Own study based on Rocznik Giełdowy (2004–2019).*

In the context of significant changes in the volume of trading in WIG20 options, indicating a decrease in liquidity, it can be considered that this factor had an important impact on the effectiveness of hedging. Along with the positive qualitative changes on the Polish options market, the desired quantitative changes in the volume of trading did not take place. The lower effectiveness of delta hedging in 2017–2018 indicates that the decrease in market liquidity has become the predominant factor in this case. The importance of the impact of the decrease in liquidity on the effectiveness of hedging is also supported by the fact that there is the frequent lack of data associated with low liquidity. For the period 2017–2018, only 341 observations were obtained in total, and taking 250 trading sessions a year, it should be 500 observations. In 2007 and 2015, no such data gaps were found. If trading in certain options disappeared during stock exchange sessions, it is difficult to talk about any possibilities of their use in delta hedging.

In its essence, delta hedging protects against minor changes in the prices of the underlying instrument – larger changes mean its lower effectiveness. Therefore, if there is a significant increase in volatility on the market, you can expect delta hedging to be less effective and vice versa. In the analyzed periods, the simple standard deviation of the daily rates of return of the WIG20 index was as follows: 2007 – 1.59%, 2015 – 1.23%, 2017–2018 – 1.08%. Therefore, while the increase in the effectiveness of delta hedging in 2015 compared to 2007 could be related to some extent to the decrease in volatility, in 2017–2018 the volatility was at the lowest level among the analyzed periods, while the effectiveness of delta hedging for the data from this period was at its lowest level. This observation also indicates that the market liquidity played the most important role here and was the cause of the decline in the effectiveness of delta hedging.

## 5. Conclusion

In order to achieve the purpose of the paper, the results of the latest research on the effectiveness of delta hedging with the use of WIG20 options were compared with the results of previous studies in this area. The reasons for changes in the effectiveness of this type of hedging were also indicated, paying attention to the qualitative and quantitative factors.

The conducted research generally confirmed the effectiveness of delta hedging using options in the Polish market, while the research hypothesis about the durability of high effectiveness of delta hedging was negatively verified. The main reason for the decrease in the effectiveness of delta hedging in the last of the analyzed periods was found to be the significant decrease in liquidity on the WIG20 options market. It should be noted that the obtained results could have been influenced by the periods included in the research.

https://doi.org/10.7172/1644-9584.90.9

In a situation of a significant impact of liquidity on the effectiveness of hedging, it is difficult to predict changes in the Polish options market in this respect, as the reasons for the decrease in the volume of trading in options are not easy to identify. Perhaps the low level of liquidity on the options market has become a self-propelling mechanism here. A decrease in the trading volume means a decrease in liquidity, and low liquidity is a factor discouraging market participants from entering into transactions.

In the Capital Market Development Strategy adopted by the Polish government on October 1, 2019, it was noted that in the case of the Polish market "in terms of the value of turnover and the variety of financial derivative instruments offered ... the OTC market is much better developed. The average daily net turnover on the OTC market in 2017 was eight times higher than the turnover in derivatives listed on the WSE" (*Uchwała Rady Ministrów* …, 2019). The most important barriers to the development of the capital market in this Strategy include, among others, insufficient efficiency, transparency and liquidity of the derivatives market.

In the context of the previously mentioned research results indicating the positive role of the derivatives market in stimulating economic growth, actions supporting the development of the Polish derivatives market, including the options market, should be considered advisable. Such actions must, however, also take into account the threats that these derivatives bring. In crisis situations, the leverage effect that occurs in the case of derivatives, strengthened by the increase in volatility, may have very negative effects on the value of investment portfolios, especially in connection with the lack of liquidity. The financial crisis which started in 2007 made these threats fully visible. However, it should be noted that while the situation on the OTC market was very difficult, the exchange-traded derivatives market handled the crisis quite well. This was related to the appropriate security and guarantee systems used on this market.

The aforementioned government strategy envisages, among others, specific actions in the field of equity and commodity derivatives. In particular, it is worth highlighting the planned possibility for the funds investing for retirement purposes to hedge market risk with derivatives. In the context of the results from the survey conducted by the National Bank of Poland in 2019 indicating the increase in trading of currency options on the Polish OTC market of 70% compared to 2016 (*Wyniki badania* …, 2019), it is also worth paying attention to this derivative. Exchange-traded currency options could become a very useful instrument for Polish exporters and importers. Such hedging strategies as protective put or protective call, which allow for effective protection against the exchange rate risk of the exporter or importer, respectively, due to their simplicity and the lack of margins securing the appropriate purchase positions on options, are interesting and possible solutions also for small and medium-sized enterprises.

**Acknowledgements**

*The paper was financed from funds allocated to the College of Management and Quality Sciences of the University of Economics in Krakow, as part of a grant for the maintenance of research potential.*

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