New hedging techniques in energy sector using barrier options

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The paper is focused on the measurement of hedging efficiency using the New 4 option strategy created by barrier options. We aim to find the way of the risk management against an underlying asset´s price drop. European down and knock-in put options are used with the combinations of vanilla call and barrier call options, where the zero-cost option strategy has to be met. Based on analysed hedging techniques, the minimum constant selling price is secured for the case of the underlying asset´s price drop. Our theoretical results of hedging are applied in the energy sector, i.e. Energy Select Sector SPDR ETF. All hedging techniques are analysed and compared to each other, but only selected variants are presented in the paper. The findings show that the using of barrier options on the hedging produces very significant reductions in risk. Finally, there is necessary to develop an effective hedging strategy, where the structure of the strike prices and the barrier levels plays an important role. According to the findings, the recommendations of the best ways are introduced for potential investors.

Keywords: *hedging technique, barrier option, option strategy, Energy Select Sector SPDR ETF*

Introduction

Financial market prices, mainly stock prices, commodity prices, foreign exchanges and other investment assets, have shown striking changes in volatility through time. Each of these kinds of the underlying assets´ price shows enormous unpredictable movements from day to day or month to month. Due to this fact, the firms or business leaders want to use effective hedging strategies, in order to avoid the disruptive consequences of their investments. Financial derivatives are an interesting opportunity to protect against market risks. Mainly barrier options introduce effective and flexible tools used in the risk management. Over the years, many financial studies are dealing with the risk management using financial derivatives. Many studies deal with the solving problem in the risk management. Brown (2001), Guay and Kothari (2003) study the managing of risk through derivatives. Hankins (2011) investigate how the firms manage risk by examining the interactions between financial and operational hedging. Loss (2012) presents the optimal hedging strategies, and Tichý (2009) focuses on currency hedging of the nonfinancial institution. To our best knowledge, our risk management using barrier options appears to be unique in this field. Hence, comparing the various risk management variants using New 4 option strategy created by barrier options fills a noticeable gap in this topic. Our theoretical results will be useful not only for financial institutions but also for academic and research community.

Hedging aims to reduce any substantial losses from the operations in future, where it is possible to hedge the values of energy, precious metals, foreign currency, and interest rate fluctuations. It is valid that the loss in spot market position is compensated by the gain in futures market position and vice versa. In our case, hedger intends to sell an underlying asset in future and wishes to eliminate the downside risk. The purpose of the paper is to hedge against price drop using New 4 option strategy. We do not avoid a price drop, but we want to secure only the minimum acceptable selling price. The methodology of the paper is based on option strategies, introduced in the papers such as Hull (2012) and Taleb (1997). Mainly barrier options introduce a new tool in the risk management. These tools are particularly attractive to hedgers in the financial market. In essence, there are four types of barrier options, i.e. UI, UO, DI, DO call/put options. Where the right to exercise either appears (IN) or disappears (OUT) on some barrier level. The barrier level can be set above (UP) or below (DOWN) the underlying asset price at the time the option is created. The barrier level must be set above (for UP options) and below (for DOWN options) the actual spot price, because otherwise, the options would be worthless. Barrier options are generally cheaper than standard options due to the underlying asset has to cross a certain barrier level. As we will see later, DI put options with the combinations of vanilla/barrier call options are the best for hedging against a price drop. More detailed characteristics of barrier options are presented by Tichý (2004) and Zhang (1998). In the paper, we discuss only European options in any detail. However, the next approach can be oriented on American options.

We aim to hedge the minimum selling price for our portfolio through New 4 option strategy using barrier options. There are 124 possibilities´ creation of this strategy using barrier and vanilla options in total. For full

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protection against price drop, there have to be used DI put options with the smallest strike price and other types of options. Our research shows that 16 types using only barrier options and 9 types using vanilla and barrier options are suitable for our analysis. We have presented selected hedging variants with the best results of the secured selling price because other ways are secured only partially. The results of our approach are applied in the energy sector, specifically, Energy Select Sector SPDR ETF. It is a fund allocated to oil gas and consumable fuels companies. However, this approach can be applied for various underlying assets. Based on individual components of replicating portfolio, the hedging techniques on these shares are proposed and compared to each other with the unsecured position. In the end, the best hedging techniques are presented in different underlying asset´s price development with the recommendations for potential institutions.

Research methodology

Our approach is based on option strategies and their using in risk management. The significant part of financial engineering are options and option strategies. These tools are also used on the new innovative financial product´s creation as it is proved by Hull (2012). Therefore, the methodology of the paper is based on these tools by which the significant role plays a valuation. Understanding of the New 4 option strategy creation is needed for its use in risk management. New 4 option strategy can be created in 3 ways. The first way is created as the buying n put options with a strike price X_1, the premium p_{1N} per option, simultaneously by selling n put options with a higher strike price X_2 the premium p_{2S} per option and by buying n put options with the highest strike price X_3 the premium p_{3B} per option. The second way is similar to the previous one with the same parameters but is created by buying call options and at the same time by selling call options and by buying put options. However, these two ways are not possible to create without initial costs. The last way fulfils the zero costs, which is created by buying n put options and at the same time by selling n call options and by buying n call options, where the strike prices should be set as $X_1 < X_2 < X_3$. Therefore, we will consider only with this way for hedging. Also, European-style of options is used for the same underlying asset and with the same expiration time.

The New 4 option strategy using only standard vanilla options was designed by Šoltés (2011). The New 1 option strategy formed by barrier options and its using in risk management was discussed by Šoltés and Harčariková (2015). Short Call Ladder strategy created by vanilla options and its using on hedging is dealt by Amaitiek et al. (2010). Also, Rusnáková and Šoltés (2012), Rusnáková (2015), Šoltés and Rusnáková, (2012; 2013) analyse the hedging against a price increase or drop by means of different options strategies using vanilla and barrier options. According to the studies mentioned, we analyse all possible ways of New 4 option strategy creation using barrier options with the aim to hedge against a price drop.

Valuation

The analysis consists of all ways of New 4 option strategy creation using barrier options in risk management. There is possible to create 124 ways of New 4 option strategies using barrier options. However, only selected variants are presented in this paper. Using DI put options with the smallest strike price are suitable for full hedging against a price drop. All combinations of DI put options together with 2 various call/call barrier options are analysed, i.e. 9 ways with the vanilla options and 16 ways only with barrier options. Choosing of secured variants have to meet the zero-cost conditions. Our theoretical results are applied to the Energy Select Sector SPDR ETF (XLE), where the evaluation of the hedger´s profitability at the maturity date is presented. Based on comparative analysis of the proposed hedging variants, the recommendations for investors are given.

The approach is based on the value of European vanilla and barrier options on the Energy Select Sector SPDR ETF with the various strike prices and the barrier levels. Real vanilla options are gained from www.finance.yahoo.com. European barrier option prices are not publicly accessible. Then, we have to calculate barrier option premiums. Authors Black and Scholes (1973) introduced basic, generally used, option pricing model and their work are considered as a significant added value in financial engineering theory and practice. However, this model cannot be used for the pricing of the barrier options. Merton (1973) modified classic version of this model for European down and knock-out call option. Formulas for eight types of the barrier options were derived by Rubinstein and Reiner (1991). Moreover, finally, Haug (2007) applied valuation formulas on all 16 types of the European style of the barrier options.

Based on Haug model (2007) we compute theoretical prices of standard European barrier call/put options, where the following input parameters are considered:

- the actual underlying spot price S_0,
- the barrier level B,
- the strike price X,
- compensation K,
- the risk-free interest rate r (derived from government bonds yields – U.S. Treasury rate, source: www.bloomberg.com),

- the implied volatility σ (we used historical volatility),
- dividend yield q,
- the time to maturity of the option t.

All derived relations of barrier call options can be found in Iacus (2011). Our calculations of selected barrier options were processed in the statistical program R.

Hedging techniques with using of barrier options

Suppose that the firm decides to hedge by using New 4 option strategy. Therefore, we analyse various hedging techniques using given option strategy by barrier options. The used way is created by buying n put options and at the same time by selling n call options and by buying n call options, where the strike prices should be set as $X_1 < X_2 < X_3$. In the analysis of hedging techniques we can consider different levels of call barrier options. Where barrier conditions for particular call barrier options with premium c_{2S} or c_{3B} are in Table 1. For easier understanding, we will consider the same level of lower D and upper U barriers for used barrier options.

Tab. 1. Call barrier options.

Type of call barrier option	Barriers	
up and knock-in (UI)	$U > X$	$U > S_0$
up and knock-out (UO)		
down and knock-in (DI)	$D < X_2 \vee D < X_3$	$D < S_0$
down and knock-out (DO)	$D = X_2 \vee D = X_3$ $D > X_2 \vee D > X_3$	

Notes: X strike price, D lower barrier, U upper barrier.
Source: own design

Let´s consider the selling n pieces of the underlying asset from our portfolio. However, we are afraid of its price fluctuation to the drop in the market. The income from the sale of the unsecured position in the amount of n pieces at time T is $n \cdot S_T$, where ST is the underlying spot price at time T.

At first, let us construct New 4 option strategy by buying n down and knock-in put options with a strike price X_1, the premium p_{1BDI} per option, the barrier level D and at the same time by selling the same amount of n call options with the strike price X_2, the premium c_{2S} per option and by buying n call options with the strike price X_3, the premium c_{3B} per option. All relations for analytical expressions of vanilla and barrier options used in our analysis are derived and presented by Rusnáková (2012). For simplifications, we have assumed the same level of lower D (for DI and DO barrier options) and upper U (for UI and UO barrier options) barriers for investigated hedging techniques in our research analysis. It is valid, that $D < X_1$ and $U > X_3$, simultaneously $D < S_0$ and $U > S_0$ should be set, where S_0 is the actual underlying spot price at the time of issue. In case of DI/DO call options, the barrier D can be set lower, equal or higher than the strike price. For UI/UO call options, the barrier U should be set higher than the strike price. Otherwise, it is classical correspondent vanilla call options.

Table 2 shows the final selling price of New 4 option strategy_1 as a sum the cash market price and the future market payoff.

Tab. 2. Final selling prices using New 4 option strategy_1.

Price scenarios of energy fund	Cash market price	Future market payoff	Final selling price
$\min_{0 \le t \le T}(S_t) > D \wedge S_T < X_1$	$n \cdot S_T$	$-n \cdot (p_{1BDI} - c_{2S} + c_{3B})$	$n \cdot (S_T - p_{1BDI} + c_{2S} - c_{3B})$
$\min_{0 \le t \le T}(S_t) \le D \wedge S_T < X_1$	$n \cdot S_T$	$-n \cdot (S_T - X_1 + p_{1BDI} - c_{2S} + c_{3B})$	$n \cdot (X_1 - p_{1BDI} + c_{2S} - c_{3B})$
$X_1 \le S_T < X_2$	$n \cdot S_T$	$-n \cdot (p_{1BDI} - c_{2S} + c_{3B})$	$n \cdot (S_T - p_{1BDI} + c_{2S} - c_{3B})$
$X_2 \le S_T < X_3$	$n \cdot S_T$	$-n \cdot (S_T - X_2 + p_{1BDI} - c_{2S} + c_{3B})$	$n \cdot (X_2 - p_{1BDI} + c_{2S} - c_{3B})$
$S_T \ge X_3$	$n \cdot S_T$	$n \cdot (X_2 - X_3 - p_{1BDI} + c_{2S} - c_{3B})$	$n \cdot (S_T + X_2 - X_3 - p_{1BDI} + c_{2S} - c_{3B})$

Source: own design

In comparison to the classical vanilla options, the barrier option premiums are always cheaper for the uncertainty of the barrier option price in the future. In every time this New 4 option strategy is created without any initial costs, i.e. the zero-cost strategy is fulfilled by relation (1):

$$n \cdot c_{2S} \ge n \cdot (p_{1BDI} + c_{3B}) \tag{1}$$

This hedging technique is the best due to higher selling call option premium. The higher strike price is, the lower call option premiums and the higher put option premiums are.

The comparison of cash market price and final selling price as it is shown by income function in Table 1, we can conclude:

The expectations of reaching the lower barrier D by underlying asset during the time to maturity and $S_T < X_1$ at the maturity date are desired. For our purpose, the incomes of final selling price are still constant in amount of $n \cdot (X_1 - p_{1BDI} + c_{2S} - c_{3B})$. By comparing with the cash market price (the unsecured position), the incomes will be higher with the given hedging strategy if $S_T \leq n \cdot (X_1 - p_{1BDI} + c_{2S} - c_{3B})$.

On the other side, if the lower barrier is not reached during time to maturity and $S_T < X_1$ or $X_1 \leq S_T < X_2$, the incomes from the final selling price are $n \cdot (S_T - p_{1BDI} + c_{2S} - c_{3B})$. In this case we hedged a constant profit in amount of $n \cdot (c_{2S} - p_{1BDI} - c_{3B})$.

If the underlying asset´s spot price at the maturity date is at an interval $X_2 \leq S_T < X_3$, then the incomes of the hedged strategy will be constant in amount of $n \cdot (X_2 - p_{1BDI} + c_{2S} - c_{3B})$. And the hedged strategy will be better than unsecured position for case $S_T \leq n \cdot (X_2 - p_{1BDI} + c_{2S} - c_{3B})$.

If the price $S_T \geq X_3$, the secured incomes will always be lower than the incomes from unsecured position in amount of $n \cdot (S_T + X_2 - X_3 - p_{1BDI} + c_{2S} - c_{3B})$.

Let us consider with hedging option´s creation as buying *n* down and knock-in put options with a strike price X_1, the premium p_{1BDI} per option, the barrier level *D* and at the same time by selling the same amount of *n* call options with the strike price X_2, the premium c_{2S} per option and by buying *n* call barrier options with the strike price X_3, where the call barrier options can be:

2A) up and knock-in call options with the barrier level U, i.e. $U > X_3$ and premium c_{3SUI} per option.

2B) up and knock-out call options with the barrier level U, i.e. $U > X_3$ and premium c_{3SUO} per option.

2C) down and knock-in call options with the barrier level D, i.e. $D < X_3$ and premium c_{3SDI} per option.

2D) down and knock-out call options with the barrier level D, i.e. $D < X_3$ and premium c_{3SDO} per option.

The expiration period has to be same for all used options. The final selling prices of New 4 option strategy_2 for used call barrier options are presented in Table 3.

Tab. 3. Final selling prices using New 4 option strategy_2.

Price scenarios of energy fund	Final selling price_2A	Final selling price_2B	Final selling price_2C	Final selling price_2D
$\min_{0\le t\le T}(S_t) > D \wedge S_T < X_1$	$S_T - p_{1BDI} + c_{2S} - c_{3BUI}$	$S_T - p_{1BDI} + c_{2S} - c_{3BUO}$	$S_T - p_{1BDI} + c_{2S} - c_{3BDI}$	$S_T - p_{1BDI} + c_{2S} - c_{3BDO}$
$\min_{0\le t\le T}(S_t) \leq D \wedge S_T < X_1$	$X_1 - p_{1BDI} + c_{2S} - c_{3BUI}$	$X_1 - p_{1BDI} + c_{2S} - c_{3BUO}$	$X_1 - p_{1BDI} + c_{2S} - c_{3BDI}$	$X_1 - p_{1BDI} + c_{2S} - c_{3BDO}$
$X_1 \leq S_T < X_2$	$S_T - p_{1BDI} + c_{2S} - c_{3BUI}$	$S_T - p_{1BDI} + c_{2S} - c_{3BUO}$	$S_T - p_{1BDI} + c_{2S} - c_{3BDI}$	$S_T - p_{1BDI} + c_{2S} - c_{3BDO}$
$X_2 \leq S_T < X_3$	$X_2 - p_{1BDI} + c_{2S} - c_{3BUI}$	$X_2 - p_{1BDI} + c_{2S} - c_{3BUO}$	$X_2 - p_{1BDI} + c_{2S} - c_{3BDI}$	$X_2 - p_{1BDI} + c_{2S} - c_{3BDO}$
$\max_{0\le t\le T}(S_t) \geq U \wedge S_T \geq X_3$	$S_T + X_2 - X_3 - p_{1BDI} + c_{2S} - c_{3B}$	$X_2 - p_{1BDI} + c_{2S} - c_{3BUO}$	-	-
$\max_{0\le t\le T}(S_t) < U \wedge S_T \geq X_3$	$X_2 - p_{1BDI} + c_{2S} - c_{3BUI}$	$S_T + X_2 - X_3 - p_{1BDI} + c_{2S} - c_{3BU}$	-	-
$\min_{0\le t\le T}(S_t) \leq D \wedge S_T \geq X_3$	-	-	$S_T + X_2 - X_3 - p_{1BDI} + c_{2S} - c_{3B}$	$X_2 - p_{1BDI} + c_{2S} - c_{3BDO}$
$\min_{0\le t\le T}(S_t) > D \wedge S_T \geq X_3$	-	-	$X_2 - p_{1BDI} + c_{2S} - c_{3BDI}$	$S_T + X_2 - X_3 - p_{1BDI} + c_{2S} - c_{3BD}$

Source: own design

Now, let´s create at hedging through Nova 1 strategy using only barrier options. The best possibilities are by buying *n* down and knock-in put options with a strike price X_1, the premium p_{1BDI} per option, the barrier level *D* and at the same time by selling the same amount of *n* down and knock-out call options with the strike price X_2, the premium c_{2SDO} per option, the barrier level *D* and by buying *n*

3A) up and knock-in call options with the strike price X_3, the premium c_{3BUI} per option and barrier level *U*.

3B) up and knock-out call options with the strike price X_3, the premium c_{3BUO} per option and barrier level *U*.

The final selling prices of New 4 option strategy_3 are presented in Table 4.

Tab. 4. Final selling prices using New 4 option strategy_3.

Price scenarios of energy fund	Final selling price_3A	Final selling price_3B
$\min_{0\le t\le T}(S_t) > D \wedge S_T < X_1$	$S_T - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$S_T - p_{1BDI} + c_{2SDO} - c_{3BUO}$
$\min_{0\le t\le T}(S_t) \le D \wedge S_T < X_1$	$X_1 - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$X_1 - p_{1BDI} + c_{2SDO} - c_{3BUO}$
$X_1 \le S_T < X_2$	$S_T - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$S_T - p_{1BDI} + c_{2SDO} - c_{3BUO}$
$\min_{0\le t\le T}(S_t) > D \wedge X_2 \le S_T < X_3$	$X_2 - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$X_2 - p_{1BDI} + c_{2SDO} - c_{3BUO}$
$\min_{0\le t\le T}(S_t) \le D \wedge X_2 \le S_T < X_3$	$S_T - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$S_T - p_{1BDI} + c_{2SDO} - c_{3BUO}$
$\max_{0\le t\le T}(S_t) \ge U \wedge \min_{0\le t\le T}(S_t) > D \wedge S_T \ge X_3$	$S_T + X_2 - X_3 - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$X_2 - p_{1BDI} + c_{2SDO} - c_{3BUO}$
$\max_{0\le t\le T}(S_t) \ge U \wedge \min_{0\le t\le T}(S_t) \le D \wedge S_T \ge X_3$	$2 \cdot S_T - X_3 - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$S_T - p_{1BDI} + c_{2SDO} - c_{3BUO}$
$\max_{0\le t\le T}(S_t) < U \wedge \min_{0\le t\le T}(S_t) > D \wedge S_T \ge X_3$	$X_2 - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$S_T + X_2 - X_3 - p_{1BDI} + c_{2SDO} - c_{3BUO}$
$\max_{0\le t\le T}(S_t) < U \wedge \min_{0\le t\le T}(S_t) \le D \wedge S_T \ge X_3$	$S_T - p_{1BDI} + c_{2SDO} - c_{3BUI}$	$2 \cdot S_T - X_3 - p_{1BDI} + c_{2SDO} - c_{3BUO}$

Source: own design

For right investor´s decision, it is necessary to choose call barrier options (UI, UO, DI, DO) depends on the type of expectations of underlying asset´s development. We can predict rapid/slowly increase or rapid/slowly drop of the underlying asset. According to this, the call barrier options are chosen for the hedging. Some options secure the final selling price only partially, other types fully. Finally, it may not be a perfect hedge, but it should remove much of the risk, and the hedger has to make a final decision.

Practical application to the energy sector

In this part, our proposed hedging variants are applied in energy sector using exchange-traded funds (ETFs), specifically Energy Select Sector SPDR ETF (referred XLE). ETFs provide an interesting way how to invest in energy sources such as oil, gas, coal or electricity. XLE fund is chosen due to its size in this category.

Now, let us suppose that in the future (January 2018) we are planning to sell 100 stocks of XLE. We are afraid a downwards price movement over the period. In this time, we aim to hedge using above mentioned New 4 option strategy created by vanilla and barrier options. Using this option strategy, we want to hedge the minimum selling price in January 2018. Traded amount of shares are 100 pieces, while the zero-cost option strategy has to be fulfilled according to relation (1). Otherwise hedging variants are excluded from our observations. For easier way, we do not consider any transaction costs and trading constraints. Next part shows some hedging variants, which meet the above-stated requirements.

Data description

The shares of XLE are traded at USD 68.38 per share on 13th September 2016. Basic key hedging information are presented in Table 5.

Tab. 5. Key hedging information.

Underlying asset	Energy Select Sector SPDR ETF (XLE)
Issue date	13th September 2016
Issue price	68.38 USD
Maturity date	19th January 2018
Multiplier	1:1
Dividend yield	3.54 %

Source: finance.yahoo.com

Vanilla options are in real traded in the market, where the dataset is obtained from finance.yahoo.com. European barrier options are calculated according to Haug model (2007) in statistical program R with the input parameters as the spot price of the underlying asset (68.38 USD), times to maturity (494 days, i.e. hedging period from 13th September 2016 to 19th January 2018), interest rate 0.67 % (gained from treasury.gov), dividend yield 3.54 % (gained from google.com/finance) and historical volatility 26.55 % (analysed for period 8th May 2015 – 12th September 2016). Selected European call/put option premiums for classic vanilla and barrier options (barriers 40 and 90 USD) are presented in Table 6.

Tab. 6. European call/put/call barrier/put barrier option premiums with barrier levels 40 and 90 on 13th September 2016.

Implied volatility [%]	**Call$_{UI}$** (90)	**Call$_{UO}$** (90)	**Call$_{DI}$** (40)	**Call$_{DO}$** (40)	**Call**	**Strike**	**Put**	**Put$_{DI}$** (40)
32.52	12.23	9.23	0.11	21.35	24.96	45	1.17	0.81
34.42	10.83	6.60	0.04	17.38	21.20	50	2.20	1.39
30.77	9.44	4.43	0.02	13.85	16.60	55	3.40	2.01
28.30	8.62	3.36	0.01	11.98	15.16	58	3.55	2.39
3.13	8.09	2.75	0.01	10.83	12.25	60	4.85	2.64
25.72	5.56	0.77	0.00	6.32	5.95	70	8.26	3.93
21.79	4.87	0.46	0.00	5.32	4.70	73	16.60	4.31
22.47	4.43	0.31	0.00	4.74	4.50	75	12.15	4.57

Notes: Option premiums are in USD.
Source: finance.yahoo.com, own calculations in statistical program R.

The dataset for our analysis consists of 39 vanilla call/put options, 128 UI/UO/DI/DO call options and 12 DI put options. The used currency of an underlying asset and option premiums is in USD. The strike prices of a real vanilla call options are considered in the range of 30 – 100. The barrier levels are selected by authors, where for lower barriers of DI/DO call/put options in the range of 30 – 60 and for upper barriers of UI/UO call options in the range of 80 - 110, all in multiples of 10. Based on the dataset, there are analysed hedging techniques with the strike prices:

1. $X_1 = 50$, $X_2 = 60$ and $X_3 = 75$,
2. $X_1 = 45$, $X_2 = 58$ and $X_3 = 73$,
3. $X_1 = 50$, $X_2 = 55$ and $X_3 = 70$,

and considered lower barrier of the level 30, 40, 50 and 60, and the upper barrier of the level 80, 90, 100 and 110. Totally, 2601 hedging variants are proposed and analysed. However, only selected variants fulfilling zero-cost option strategy are presented in this paper. Also for easier way to showing results, the same barrier for UI/UO options (the level 90 USD) and DI/DO options (the level 40 USD) are used.

Results and discussion

Given hedging techniques have secured us a minimum acceptable selling price of the underlying asset, where the zero-cost option conditions are preferred. The XLE actual spot price is 68.38 USD, and we expect XLE price drop in January 2018. According to the first hedging technique, we will buy 100 DI put options with the strike price 50, the barrier level 40, the premium 1.39 per option and simultaneously, we will sell 100 call options with the strike price 55, the premium 16.60 per option and buy 100 call options with the strike price 70 and the premium 5.95 per option. This hedging technique is the simplest of all variant. In this example, Table 7 lists the final selling prices in USD for a case of various future XLE price scenarios.

Tab. 7. Final selling prices using New 4 option strategy_1.

Price scenarios of XLE	**Cash market price**	**Final XLE selling price**	**Final selling price of XLE per share**		**Final selling price of hedging per share**	
			min	**max**	**min**	**max**
$\min_{0\le t\le T}(S_t) > 40 \wedge S_T < 50$	$100 \cdot S_T$	$100 \cdot S_T + 926.16$	40.00	50.00	49.26	59.26
$\min_{0\le t\le T}(S_t) \le 40 \wedge S_T < 50$	$100 \cdot S_T$	5,926.16	0.00	50.00	59.26	59.26
$50 \le S_T < 55$	$100 \cdot S_T$	$100 \cdot S_T + 926.16$	50.00	55.00	59.26	64.26
$55 \le S_T < 70$	$100 \cdot S_T$	6,426.16	55.00	70.00	64.26	64.26
$S_T \ge 70$	$100 \cdot S_T$	$100 \cdot S_T - 573.84$	70.00	∞	64.26	∞

Source: own design

There is compared cash market price with final selling price at various XLE price development during the time to maturity and at the maturity date, where the following conclusions are formulated:

- If the spot price of XLE shares during the time to maturity does not reach or reaches the barrier 40 USD and is lower than 64.26 USD, then the hedged variant 1 is still better than the unsecured position.
- Hedged position secures constant selling price in the amount of 59.26 USD per share for the case of reaching the barrier 40 USD during the time to maturity and XLE price lower than 50 USD, and the higher constant selling price 64.26 USD per share in interval <55, 70> of XLE spot price at the maturity date.

Another hedging variants are created as combinations of barrier options. The second variant can be created by buying 100 DI put options with the strike price 50, the barrier level 40, the premium 1.39 per option and at the same time by selling 100 call options with the strike price 55 and the premium 16.60 per option and by buying 100

2A) UI call options with a strike price 70, the barrier level 90, the premium 5.56 per option, 2B) UO call options with a strike price 70, the barrier level 90, the premium 0.77 per option,

2C) DI call options with a strike price 70, the barrier level 40, the premium 0.00 per option,

2D) DO call options with a strike price 70, the barrier level 40 and the premium 6.32 per option.

The last (the third) variant of New 4 option strategy creation is by buying 100 DI put options with the strike price 50, the barrier level 40, the premium 1.39 per option and at the same time by selling 100 DO call options with the strike price 55, the barrier 40, the premium 13.85 per option and by buying 100

3A) UI call options with a strike price 70, the barrier level 90, the premium 5.56 per option.

3B) UO call options with a strike price 70, the barrier level 90 and the premium 0.77 per option.

The comparison of all analysed hedging techniques at various XLE price development during the time to maturity and at the maturity date are shown in Table 8 with a provided more detailed illustration of selected hedging variants. The results from Table 8 shows that the best hedging technique is variant 2C securing the highest selling price in the amount of 65.21 USD per share. Also, variant 2B is interesting for hedgers, where the selling price is in the amount of 64.44 USD.

Tab. 8. Comparison of the hedging techniques 2A – 2D and 3A – 3B.

Price scenarios of energy fund	**Final selling price_2A**	**Final selling price_2B**	**Final selling price_2C**	**Final selling price_2D**	**Final selling price_3A**	**Final selling price_3B**
$\min_{0\leq t\leq T}(S_t) > 40 \wedge S_T < 50$	$100 \cdot S_T + 965.64$	$100 \cdot S_T + 1{,}444.45$	$100 \cdot S_T + 1{,}521.07$	$100 \cdot S_T + 889.02$	$100 \cdot S_T + 690.72$	$100 \cdot S_T + 1{,}169.53$
$\min_{0\leq t\leq T}(S_t) \leq 40 \wedge S_T < 50$	5,965.64	6,444.45	6,521.07	5,889.02	5,690.72	6,169.53
$50 \leq S_T < 55$	$100 \cdot S_T + 965.64$	$100 \cdot S_T + 1{,}444.45$	$100 \cdot S_T + 1{,}521.07$	$100 \cdot S_T + 889.02$	$100 \cdot S_T + 690.72$	$100 \cdot S_T + 1{,}169.53$
$55 \leq S_T < 70$	6,465.64	6,944.45	7,021.07	6,389.02	-	-
$\min_{0\leq t\leq T}(S_t) > 40 \wedge 55 \leq S_T < 70$	-	-	-	-	6,190.72	6,669.53
$\min_{0\leq t\leq T}(S_t) \leq 40 \wedge 55 \leq S_T < 70$	-	-	-	-	$100 \cdot S_T + 690.72$	$100 \cdot S_T + 1{,}169.53$
$\max_{0\leq t\leq T}(S_t) \geq 90 \wedge S_T \geq 70$	$100 \cdot S_T - 534.36$	6,944.45	-	-	-	-
$\max_{0\leq t\leq T}(S_t) < 90 \wedge S_T \geq 70$	6,465.64	$100 \cdot S_T - 55.55$	-	-	-	-
$\min_{0\leq t\leq T}(S_t) \leq 40 \wedge S_T \geq 70$	-	-	$100 \cdot S_T + 21.07$	6,389.02	-	-
$\min_{0\leq t\leq T}(S_t) > 40 \wedge S_T \geq 70$	-	-	7,021.07	$100 \cdot S_T - 610.98$	-	-
$\max_{0\leq t\leq T}(S_t) \geq 90 \wedge \min_{0\leq t\leq T}(S_t) > 40 \wedge S_T \geq 7$	-	-	-	-	$100 \cdot S_T - 809.28$	6,669.53
$\max_{0\leq t\leq T}(S_t) \geq 90 \wedge \min_{0\leq t\leq T}(S_t) \leq 40 \wedge S_T \geq 7$	-	-	-	-	$200 \cdot S_T - 6{,}309.28$	$100 \cdot S_T + 1{,}169.53$
$\max_{0\leq t\leq T}(S_t) < 90 \wedge \min_{0\leq t\leq T}(S_t) > 40 \wedge S_T \geq 70$	-	-	-	-	6,190.72	$100 \cdot S_T - 330.47$
$\max_{0\leq t\leq T}(S_t) < 90 \wedge \min_{0\leq t\leq T}(S_t) \leq 40 \wedge S_T \geq 70$	-	-	-	-	$100 \cdot S_T + 690.72$	$200 \cdot S_T - 5{,}830.47$

Source: own design

Graphical comparison of selected variants is illustrated below in Figure 1.

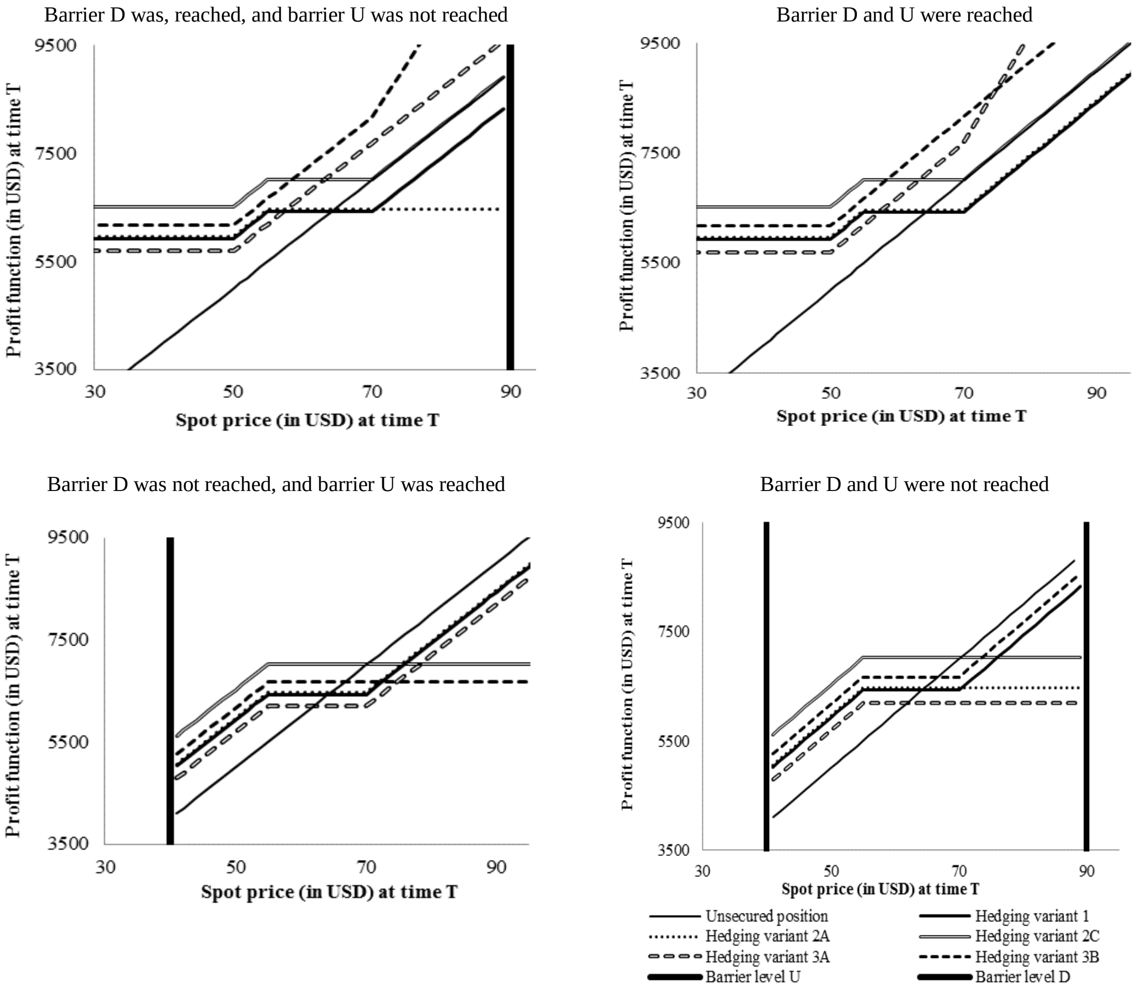

Fig. 1. Comparison of the selected analysed hedging techniques.
Source: own design

Let us look at Table 8 and Figure 1, where the following conclusions are valid:

- If the XLE spot price during the time to maturity drops under lower barrier 20 USD and does not grow above upper barrier 90 USD and is lower than 58.52 USD at the maturity date, then the variant 2C is still better than otherwise hedging variants. Otherwise, the variant 3C is better. If we compare only variants 2C and 3A, the hedging variant 2C generates us the better income up to XLE price of 63.30 USD.
- If the both of barrier levels are reached, the variant 2C is better up to spot price 58.52 USD, then the variant 3C from the interval <58.52, 74.79>, otherwise the variant 3B. These three variants secure the higher selling price than the unsecured position.
- For the third case, if the lower barrier is not reached and the upper barrier is reached during the time to maturity, the variant 2C secures higher income in interval <40, 70.21>. Otherwise, the unsecured position is better up to the endlessly.
- In the last case, the both of barrier levels are not reached during the time to maturity; then the results are the same as in the third case. However, the income from the unsecured position is limited up to upper barrier 90 USD.
- Finally, we will recommend the hedging variant 2C as one way to secure the higher minimum selling price for hedgers.

All hedging techniques creations using barrier options are very interesting in a price drop. Barrier option premium is always cheaper than classic vanilla option premiums according to Taleb (1997). In our expected XLE price scenario, i.e. the lower barrier D is reached during the time to maturity, and the XLE spot price at the maturity date is lower than 50, the variant 2C is the best in comparison to others, where the minimum selling price in the value of 65.21 USD per share is secured. However, the results of our analysis reveal that the hedger´s choice of the barrier options in the hedging techniques depends on the expectations of the underlying asset´s price development. Hedgers can choose between knock-in and knock-out barrier options based on zero-cost option strategy. If there is expected strong drop/increase, the knock-in options are chosen. In this case, the option is activated after reaching the barrier level. Otherwise, if there is expected only moderately drop/increase, the knock-out options are chosen, when they are deactivated after reaching the barrier level. Finally, all designed hedging variants are better as the unsecured position for our expected XLE price drop. Therefore, the final decision is at hedger´s expectations and willingness to take risks. If the hedger´s expectations do not meet, they could gain a loss in comparison to the unsecured position.

Conclusion

High volatility scares investors, firms and others market participants and fear can impact the market itself. Due to sustained drops in the market, the risk management appears as an interesting way of solving this problem. The paper aimed to introduce the hedging analysis against underlying asset´s price drop using New 4 option strategy created by barrier options. In the beginning, the paper presented the overview of the literature and the research methodology. To the best of our knowledge, the only little research has investigated the hedging techniques using barrier options.

The main purpose of this approach is to jointly analyse and compare various ways of New 4 option strategy creation using barrier options and their application in the energy sector, i.e. Energy Select Sector SPDR ETF. The primary aim is to choose hedging variants, which meet the requirements of zero-costs. Our results show that using the barrier options indicate the more alternatives for hedging, where all variants are analysed. Following the mentioned assumptions, the only best hedging techniques are introduced in detailed description as well. Also, numerical examples on given hedging techniques are presented, where the variant 2C, i.e. created with DI put, call and DI call options ensure the highest income at expected intervals of the XLE shares spot price at the maturity date. Others variants are not excluded from our observations because their income is interesting too. However, they are not presented in the paper. However, the final decision, what combinations of the strike prices, the lower and the upper barrier levels and type of options, is on the hedger and his expectations about underlying asset´s price development and the willingness to take a risk. Our results can be important for practitioners, individual investors, firms, others market participants and the general public. The main contribution of the paper is to highlight the one type of derivative contracts, i.e. barrier options, whose payoff structures produces a better hedging results against downside risk.

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