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Derivatives on regional commodity exchanges

The objectives of the paper are as follows: an analysis of possibilities and conditions for development of derivatives on regional commodity exchanges and a proposition of extending derivatives assortment on commodity exchanges through implementation of lookback options in Poland.

The paper discusses conditions that are favourable for or may restrain the development of derivatives on regional commodity exchanges. It also presents an example of lookback option pricing on the wheat market.

Finally, it describes reasons of differences in the level of development of derivatives on agricultural markets in Europe and the United States.

1. Introduction

Classic commodity derivatives, i.e. futures, forward and options contracts have been in existence for a long time. However, 1970s have become a kind of turning point in evolution of derivatives applications as well as in financial engineering, too. At that time standard options pricing models were carried out and options were introduced to organised exchanges. Basics for a future market of exotic options were forming simultaneously. Exotics are the options that regard individual preferences of investors.

In the next years the assortment of exotic options has been consequently evolving and investors started to notice possible benefits connected with their employment. The most important of the benefits are: a lower price and non-standard character. Very often exotic options are relatively inexpensive when compared to a linear combination of vanilla options. They are also very flexible. This means that if an instrument satisfying investors' needs does not exist, it can always be "financially engineered". That is not always possible when using only standard options.

In the world, exotic options are generally traded on over-the-counter markets, although in the United States the most standard of exotics: barrier and lookback options have been introduced also to formal markets.

In 1990 in Poland in consequence of political changes some commodity exchanges were founded. At the beginning, only cash transactions took place on all

of them. Since 1995 the Pozna? Exchange and since 1997 the Warsaw Commodity Exchange have implemented European and American call and put options on pork-halves, beef-quarters, maize, consumption and feed wheat. Then in 1998 these two exchanges introduced also futures contracts on consumption and feed wheat and on live hogs. The main options writer was the Agricultural Market Agency (AMA). Its basic purpose is to regulate prices on an agricultural market. In the years 1997-2000 options and futures contracts took 5-10% of volume of trade on the two above-mentioned exchanges. Annual volume of trade in derivatives on agricultural items in Poland acquired 0.1% of volume of parallel trade in the United States. There are numerous reasons of such a situation in Poland:

- mean infrastructure of commodity exchanges and lack of law regulations;
- regulative role of the Agricultural Market Agency eliminating some market risk;
- unsatisfactory investors' knowledge of derivatives;
- no speculators on futures markets.

Implementation of variety of derivatives, for example options on futures or exotic options such as barrier and lookback options could stimulate to some extent the Polish market of derivatives. The specific nature of options on futures and barrier options has been discussed by Krawiec and Krawiec (2002).

The aims of the paper are as follows: description of lookback options and methods of their pricing; presentation of an example of lookback option pricing and its comparison with standard options and finally an analysis of chances for development of derivatives on regional exchanges in Poland.

2. Characteristics of lookback options and pricing methods

Lookback options belong to the group of path-dependent options. This means that their prices depend on prices of underlying assets in the time "T" up to options exercising. There are two basic types of lookback options due to which one of the elements influencing the payoff function – the underlying asset price "S" or exercise price "X" is replaced by an extreme value (maximum or minimum). These are: floating-strike lookback options and fixed-strike lookback options. In fact, floating-strike lookback options are more popular so further reflections in the paper will focus only on them.

A lookback call option provides the right to buy an underlying asset at the lowest price that has been observed in the time from option's writing till its exercising. While a lookback put option gives the right to sell an underlying asset at the highest market price during the life of the option. Exercising of these two types of options is always profitable on the option maturity day, so due to Weron and Weron (1998) their prices are twice as high as prices of vanilla options. These differences may be even higher in the case of underlying assets with high volatilities.

When an underlying asset price at the time of option's maturity: "T" is denoted by S (T), then a writer of a call option pays its owner an amount equal to:

$$K_C = S(T) - S_{min}(0,T),\qquad(1)$$

while a writer of a put option pays an amount equal to:

$$K_p = S_{max}(0,T) - S(T),\qquad(2)$$

where:
- $S_{min}(0,T)$ – the minimum price of underlying asset in the time $(0, T)$,
- $S_{max}(0, T)$ – the maximum price of underlying asset in the time $(0, T)$.

The difference between lookback and vanilla options is the fact that the exercise price of vanilla option is always pre-specified, while the exercise price of lookback option is equal to the extreme market price of underlying asset during the life of the option. That is why lookback options are referred to as extremum-dependent options. It is also worth to mention that an American lookback option gives the right to exercise at any time until maturity. Then, the extreme price of underlying asset which has been observed till option's exercising is taken at a settlement. In fact, earlier exercising of lookback options is not profitable usually. Hence, investors prefer European lookback options and they are the majority of lookback options traded.

In the case of lookback and barrier options a way of sampling underlying assets prices is very important. In practice it means a choice between continuous and discrete methods. Lookback options pricing theory is based on an assumption of continuous measurement, but actually the underlying assets values are monitored with a lower frequency – usually once a day. However, values of options with discrete sampling of underlying assets prices are lower than those of options with continuous monitoring of underlying assets prices (Ravindran, 1998).

In general, there are two basic methods of lookback options pricing: analytic and binomial. Goldman *et al.* (1979) provided closed-form solutions to price European lookback options on nondividend paying stocks when the assumption of a continuous time-sampling period is used. These are as follows:

for lookback call option (for t = 0):

$$C_l = S_0 N(a_1) - S_0 \frac{\sigma^2}{2r} N(-a_1) - S_{min} e^{-rT} \left[N(a_2) - \frac{\sigma^2}{2r} e^{Y_1} N(-a_3) \right],\qquad(3)$$

where:

$$a_1 = \frac{\ln(S_0 / S_{min}) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}},$$

$$a_2 = a_1 - \sigma\sqrt{T},$$

$$a_3 = \frac{\ln(S_0 / S_{\min}) + (-r + \sigma^2 / 2)T}{\sigma\sqrt{T}},$$

$$Y_1 = \frac{2(r - \sigma^2 / 2)\ln(S_0 / S_{\min})}{\sigma^2},$$

and:

S_0 – the underlying asset price at the time t = 0,

$N(a_i)$ – the cumulative probability distribution function for a variable that is normally distributed with a mean of 0 and a standard deviation of 1,0 for i = 1, 2, 3 (i.e. it is the probability that such a variable will be less than a_i),

σ – volatility of underlying asset prices,

r – risk-free rate,

T – time to maturity,

$S_{\min}$ – minimum of asset values sampled during the time t ≤ T;

for lookback put option (for t = 0):

$$P_l = S_{\max}e^{-rT}\left[N(b_1) - \frac{\sigma^2}{2r}e^{Y_2}N(-b_3)\right] + S_0\frac{\sigma^2}{2r}N(-b_2) - S_0N(b_2), \qquad (4)$$

where:

$$b_1 = \frac{\ln(S_{\max} / S_0) + (-r + \sigma^2 / 2)T}{\sigma\sqrt{T}},$$

$$b_2 = b_1 - \sigma\sqrt{T},$$

$$b_3 = \frac{\ln(S_{\max} / S_0) + (r - \sigma^2 / 2)T}{\sigma\sqrt{T}},$$

$$Y_2 = \frac{2(r - \sigma^2 / 2)\ln(S_{\max} / S_0)}{\sigma^2}.$$

The meaning of parameters is the same as for lookback call option with one exception: $S_{\max}$ means maximum of asset values sampled in the time t ≤ T.

Both the European and American lookback options can be priced using the binomial method (Nelken, 2000).

3. A lookback option pricing example

To illustrate lookback options pricing methods, an option contract on 50 tones of wheat has been constructed. At the moment of its writing e.g. on April 3, 2002 one tone of wheat cost 430 Polish zloties (PLN) on the Pozna? Exchange, while 1 USD cost at that time 4 PLN. Historical volatility of wheat prices, computed accor-

ding to the method proposed by Hull (2000) on the base of monthly data collected from April 2001 to March 2002 on regional market of Poznan, equalled "σ" =
27.2%. The lowest and the highest market prices of wheat in the considered time
were the following: S_{max} = 501 PLN/t and S_{min} = 420 PLN/t. The risk-free rate "r"
in April 2002 in Poland evaluated on the base of treasury bills according to the
formula given by Deigler (1997) was equal to 10%. Time to maturity T = 90 days
(it is 1/4 of year).

In order to price proposed European lookback call and put options the *Deriva-
Gem* programme (Hull, 2000) has been employed. Moreover, some important assumptions were undertaken: prices of wheat follow a log-normal distribution and
there are no transaction costs. It means no brokerage and no taxes on commodity
exchanges transactions. Such taxes are not paid in Poland at present.

Thus, for the considered parameters: S_0 = 430 PLN/t; S_{min} = 420 PLN/t; S_{max}
= 501 PLN/t; r = 10%; σ = 27.2%; T = 90 days, the estimated value of lookback
call option is C_l = 50.40 PLN/t, while the lookback put value is P_l = 68.90 PLN/t.
On the contrary, values of vanilla options with analogous input parameters are as
follows: value of a call option with exercise price S = S_{min} = 420 PLN/t is equal to
C = 34.30 PLN/t and the value of vanilla put with exercise price S = S_{max} = 501
PLN/t equals P = 63.60 PLN/t. These results confirm that lookback options are
more expensive than standard vanilla options. This is an exception, because prices
of other exotic options are usually lower.

It is also worth to mention that volatility influences prices of lookback options
much stronger than those of vanilla contracts. In the case of standard options, volatility affects probability of running of only one element that influences the payoff value – i.e. of market price of underlying asset. In the case of lookback options, uncertainty affects also another element – exercise price. This may be observed when comparing Vega values for vanilla and lookback options. If Vega is
high, the price of the option is very sensitive to small changes in volatility σ. If
Vega is low in absolute terms, volatility changes have relatively little impact on
the price of the option. The value of Vega for the proposed lookback call option is
equal to 1.5∗, while for the adequate vanilla option Vega = 0.78. Considering
lookback put: Vega = 1.19∗∗, while Vega for suitable vanilla put is 0, 59. One
may state that values of lookback options are twice as sensitive to changes in historical volatilities of underlying assets prices as those of vanilla options.

Hence lookback options are excellent tools for investors who speculate on a
volatility market. It is worth to cite the Arcsine's maxim basing on a specific nature of distribution of underlying asset prices which determines a moment when
the price of underlying ought to reach the extreme level. According to Arcsine the
highest probability of attaining minimum or maximum occurs in the beginning of
option's life. If at that time there is no change in the current trend, one should
consider selling the option.

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* meaning similar to this in formula (3).
**meaning similar to this in formula (4).

Moreover, analysing commodity options pricing, one should notice an element that has not been a subject of my research, yet. The options pricing models presented in the paper do not take into account the so called convenience yield which is defined as a measure of the benefits from ownership of an asset that are not obtained by the holder of a long futures contract on the asset (Hull, 2000). Ravindran (1998) pays attention to this problem and mentions the convenience yield together with other factors affecting commodity options values. For sure, the problem of convenience yield influence on values of commodity options should be analysed and this will become a subject of my future research.

Let us take into account that in April 2002 an investor took long positions in lookback call option and standard options. On the day of maturity – July 2, 2002 the price of wheat on a spot market was equal to $S_T = 440$ PLN/t. Extreme prices observed during the option's life were the following: $\hat{S}_{min} = 420$ PLN/t and $\hat{S}_{max} = 517$ PLN/t. Profits and losses from the options exercising gained by the investor who took long positions (considering option premiums that were paid) are as follows:

lookback options:

$\quad$ call: $z_1 = S_T - \hat{S}_{min} - C_1 = 440 - 420 - 50.40 = -30.40$ PLN/t;

$\quad$ put: $z_2 = \hat{S}_{max} - S_T - P_1 = 517 - 440 - 68.90 = 8.10$ PLN/t;

vanilla options:

$\quad$ call: $z_3 = S_T - S_{min} - C = 440 - 420 - 34.30 = -14.30$ PLN/t;

$\quad$ put: $z_4: S_{max} - S_T - P = 500 - 440 - 63.60 = -3.60$ PLN/t.

At high fluctuation in prices observed on the wheat market only the lookback put option is profitable. In practice, investors on derivatives markets apply hedging strategies: Chriss (1997), Hull (2000), Nelken (1996, 2000). Lookback options, described in the paper, together with standard options let create strategies reducing risk of investments. Because of their high prices, lookback options become very often elements of compound exotic options. One of the most popular combinations linking characteristic features of lookback and barrier options lets reduce high prices of lookback options. Implementation of a barrier results in reduction in probability of exercising the option, so the premium of the option is also lower. Another way to decrease prices of lookback options is to shorten the time in which underlying asset prices are observed (for example only the last month of the option's life). Of course this reduces probability of gaining the best price and decreases possible payoff value, but such an option is of course cheaper.

4. Conclusions

At the moment the most developed market of derivatives on commodity exchanges is that of the United States. Basic factors which have influenced its evolution are as follows:
- big and liquid spot market on agricultural products;
- risk occurring on a cash market;

- large number of investors interested in hedging;
- large speculators share assuring liquidity of futures transactions;
- high level of investors' knowledge of derivatives.

In the European Union an attempt to develop trade in derivatives to a large scale did not succeed. In such countries as France, Germany or England there are good conditions for development of derivatives, but there is also a large-scale institutional intervention on agricultural markets. The Common Agricultural Policy of the European Union has led to reduction in risk of prices on spot markets. The risk which is the main reason for futures transactions. Limiting of expensive Common Agricultural Policy in future may change the situation and result in better development of derivatives.

In Poland the situation on the agricultural market is a little bit different. Although one of the tasks of the Agricultural Market Agency is an intervention on the agricultural market in order to regulate prices, but the scale of this intervention is much smaller. The prices regulation on the agricultural market in Polish conditions is expensive and therefore criticized. Perhaps in 2004 Poland will join the European Union. Agreement on joining the EU includes organizational and law regulations concerning activities of commodity exchanges and derivatives markets.

In the end of 2000 the Polish Parliament passed the bill about commodity exchanges which fulfils requirements of the European Union. In 2002 the Polish Government enacted a decree regulating activities of commodity brokerage houses.

However in practice one may notice lack of efficient infrastructure linking commodity exchanges with brokerage houses. There are some proposals suggesting employment of existing net of brokerage houses of the Warsaw Stock Exchange for the needs of commodity exchanges.

At present in Poland there is a well developed spot market and risk of prices occurs on the agricultural market. Factors which stunt the progress in derivatives are as follows:

- small number of investors who practice hedging by the use of derivatives;
- no speculators on future markets;
- investors' poor knowledge of derivatives.

An important element affecting the development of derivatives market on regional exchanges should be scientific researches. Character of commodity exchanges demands different approach to employ methods which are also known on capital markets. Regional commodity exchanges exist in certain political and economic conditions with different intensity of public interventionism, with diversified risk-free rates, volatilities and convenience yields. The example of loookback option pricing, presented in the paper, shows that it is not easy to adopt and transfer well known methods from capital to commodity market. Implementation of some exotic options could extend the offer for investors on commodity markets, but must be preceded by theoretical and applied researches. Such a research has been undertaken in the paper.

Recently in Poland a conception of creating one strong commodity exchange in Warsaw has appeared. Anyway, there is a question: What will happen when Poland joins the European Union? The proposed subsidies for agricultural production in Poland are to acquire 25-40% of those for farmers from the European Union and it will take 7-10 years to gain 100%. Thus unequal conditions within the European Union will bring about risk of prices on the agricultural market in Poland. From this results a need to develop research on derivatives themselves and derivatives markets on regional exchanges in Poland and other countries such as Hungary or the Czech Republic.

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